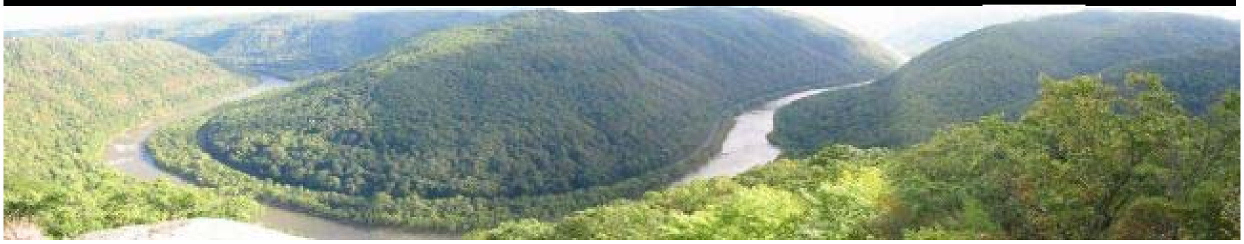
Eastern Rivers and Mountains Network
Inventory and Monitoring Program



"To protect your rivers, protect your mountains"
Emperor Yu of China, 1600 BC

New River Gorge
photo by Frank Sellers

Long-Term Ecological Monitoring Program:

Phase 1 Report

Eastern Rivers and Mountains Network
Inventory and Monitoring Program

US Department of the Interior
National Park Service

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Draft submitted October 1, 2004

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PREFACE

In 2003, nine national park service units in Pennsylvania, New York, New Jersey, and West Virginia, collectively referred to as the Eastern Rivers and Mountains Network began the process of developing and implementing a long-term ecological monitoring program. This report summarizes one year of progress in designing that program. Completion of a final monitoring plan for the network is anticipated to take five years and involve three phases. Phase I, described in chapters one and two of this report, involves defining goals and preliminary objectives; identifying, evaluating, and synthesizing existing data; providing an overview of park and network natural resources and management issues; and developing draft conceptual ecological models of major ecosystems. Phases II and III will involve selection of indicators/vital signs (Phase II) and the full development of sampling designs, sampling protocols, data management, analysis and reporting guidelines (Phase III).

This document and the material contained herein should be considered a work in progress. In fact, the Phase I report is considered a *Draft* until submission of Phase II. Over the course of the next year additional data mining and synthesis activities will take place, current inventories and other projects will potentially highlight as yet unidentified significant natural resources and issues, and, most importantly, a series of additional scoping and development meetings (including a review of the *Draft* Phase 1 Report) at the park and network level will take place. Finally, the Science Advisory Committee will also have opportunities to inform, evaluate, and guide the development of this program.

The overall process that this network has followed in planning, designing, and implementing its vital signs monitoring program, as well as additional information on the National Inventory and Monitoring (I&M) Program, is described in more detail at the NPS Inventory & Monitoring website (http://science.nature.nps.gov/im/index.htm).

This report, along with all appendices and other supporting documents as well as additional information on the Eastern Rivers and Mountains Network is available from network's website (http://www1.nature.nps.gov/im/units/ermn/index.htm).

"To protect your rivers, protect your mountains"
Emperor Yu of China, 1600 BC

New River Gorge
photo by Frank Sellers

EXECUTIVE SUMMARY

Knowing the condition of natural resources in national parks is fundamental to the National Park Service's (NPS) ability to manage park resources "unimpaired for the enjoyment of future generations" as mandated by the National Park Service Organic Act of 1916. National Park managers across the country are confronted with increasingly complex and challenging issues that require a broad-based understanding of the status and trends of park resources to inform the management decision-making process. This type of understanding is also necessary to effectively work with other government agencies and the public for the benefit of park resources.

To address this need, NPS has implemented a strategy known as "vital signs monitoring" to develop scientifically sound information on the status and long-term trends of park ecosystems and to determine how well current management practices are sustaining those ecosystems.

National parks have been grouped into 32 vital signs networks linked by geographic similarities, common natural resources, and resource protection challenges. The network approach facilitates collaboration, information sharing, and economies of scale in natural resource monitoring. The approach also will provide parks with a "minimum infrastructure" to initiate natural resource monitoring.

The Eastern Rivers and Mountains Network (ERMN) includes nine park units in Pennsylvania, New York, New Jersey, and West Virginia. The ERMN parks range in size from approximately 160 to 70,000 acres and generally consist of a mosaic of forested hillsides and floodplains, streams and rivers, tallus slopes and cliffs, vernal pools and wetlands, open fields and agriculture. The ERMN parks formed around rivers contain some of the most significant water resources and water-based recreational activities in the National Park system.

Dominant natural resource management issues in the ERMN include maintaining and improving water quality of large rivers and tributary streams and maintaining the integrity of a diverse set of terrestrial ecosystems. The world class waters of the ERMN support exceptional water-based recreation activities and globally significant natural resources that are threatened by acid mine drainage, fecal coliform bacteria, and headwater urbanization, among other things. Similarly, the biologically diverse suite of terrestrial systems is threatened by invasive species, atmospheric deposition, and urbanization surrounding parks, among other threats.

Initial planning efforts began in 2002 when the ERMN received funding to conduct baseline inventories in its parks to support early development of the monitoring plan. In the fall of 2003, Matthew Marshall was hired as Network Coordinator and Nathan Piekielek was hired as Network Data Manager to begin, in earnest, the development of the ERMN Monitoring Program. Both are stationed at the Pennsylvania State University.

Completion of the final ERMN Monitoring Plan is anticipated to take five years and involve three phases. Phase I, described in chapters one and two of this report, involves the definition of goals and preliminary objectives; identifying, evaluating, and synthesizing existing data; providing an overview of park and network natural resources and management issues; and developing draft conceptual ecological models of major ecosystems. Phases II and III will involve selection of indicators/vital signs (Phase II) and the full development of sampling designs, sampling protocols, data management, analysis and reporting guidelines (Phase III due in December 2006).

In the fall of 2002, the first Board of Directors Meeting took place with subsequent meetings to occur annually thereafter. The seven-member Board of Directors consists of five superintendents, one representing each ERMN park unit, the Northeast Region I&M Coordinator, and one of the Northeast Region's Chief Scientists. The Board's role is to ensure program accountability and maintain its relevance to individual park units' needs.

A network Science Advisory Committee is also being organized to assist and oversee program development and ensure scientific quality and integrity. This committee currently consists of seven members, chaired by the ERMN Coordinator. Additional members will be added as the program develops and areas of expertise needed are identified.

During the fall and springs of 2003 the Coordinator, Data Manager, and a Penn State Research Associate (Jennifer DeCecco) made several visits to each park to meet with Natural Resource Managers and other park staff to discuss priority natural resources, threats to those resources, dominant management issues, as well as current monitoring programs. Relevant park documents and other literature were obtained and reviewed. Information gathered from this data-mining effort, literature review, and scoping meetings provided the primary base of knowledge with which the following Phase 1 report was generated.

The ERMN identified three dominant, general ecosystems (Large Rivers, Tributary Watersheds and associated Wetlands, and Terrestrial Ecosystems) for initial conceptual ecological modeling. These models are essential for designing a scientifically credible monitoring strategy and are intended to formalize current understanding of system processes and dynamics, identify linkages of processes across disciplinary boundaries, identify the bounds and scope of the system of interest, and contribute to communication among scientists and program staff, between scientists and managers, and with the general public. These models are simplifications of complex systems that will help the NPS and its partners identify critical indicators, i.e., 'vital signs' of park ecosystems.

Over the next year, this Draft Phase I Report will be reviewed by the National I&M Program Office, Regional Science and Park Staff, the Board of Directors, and the Science Advisory Committee. Through this process, the Report and Conceptual Models will be modified and refined to ultimately serve the important purpose of facilitating discussion at the Vital Signs Selection Workshop (also to be held in FY05). The results of this workshop will produce a priority list of Vital Signs to be monitored. A revised Phase I Report and this Priority list of

Vital Signs will be submitted on October 1, 2005 as the ERMN Phase II Report (i.e., the first three chapters of the ERMN Monitoring Plan).

CHAPTER 1-- INTRODUCTION AND BACKGROUND

1.1 The Importance and Purpose of Ecological Monitoring

Knowing the condition of natural resources in national parks is fundamental to the National Park Service's (NPS) ability to manage park resources "unimpaired for the enjoyment of future generations" as mandated by the National Park Service Organic Act of 1916. National Park managers across the country are confronted with increasingly complex and challenging issues that require a broad-based understanding of the status and trends of park resources as a basis for making decisions and working with other agencies and the public for the benefit of park resources. For years, managers and scientists have sought a way to characterize and determine trends in the condition of parks and other protected areas to assess the efficacy of management practices and restoration efforts and to provide early warning of impending threats. The challenge of protecting and managing a park's natural resources requires a multi-agency, ecosystem approach because most parks are open systems, with threats such as air and water pollution, or invasive species, originating outside of the park's boundaries. An ecosystem approach is further needed because no single spatial or temporal scale is appropriate for all system components and processes; the appropriate scale for understanding and effectively managing a resource might be at the population, species, community, or landscape level, and in some cases may require a regional, national or international effort to understand and manage the resource. National parks are part of larger ecosystems and must be managed in that context.

Natural resource monitoring provides site-specific information needed to understand and identify change in complex, variable, and imperfectly understood natural systems and to determine whether observed changes are within natural levels of variability or may be indicators of unwanted influences. Thus, monitoring provides a basis for understanding and identifying meaningful change in natural systems characterized by complexity, variability, and surprises. Monitoring data help to define the normal limits of natural variation in park resources and provide a basis for understanding observed changes; monitoring results may also be used to determine what constitutes impairment and to identify the need to initiate or change management practices. Understanding the dynamic nature of park ecosystems and the consequences of human activities is essential for management decision-making aimed to maintain, enhance, or restore the ecological integrity of park ecosystems and to avoid, minimize, or mitigate ecological threats to these systems (Roman and Barrett 1999).

The intent of park vital signs monitoring is to track a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values. The elements and processes that are monitored are a subset of the total suite of natural resources that park managers are directed to preserve "unimpaired for future generations," including water, air, geological resources, plants and animals, and the various ecological, biological, and physical processes that act on those resources. In situations where natural areas have been so highly altered that physical and biological processes no longer operate naturally (e.g., on park lands near developed areas where a history of flood and fire control has fundamentally altered natural disturbance regimes), information obtained through monitoring can help managers understand how to develop the most effective approach to restoration or, in cases where restoration is impossible, ecologically sound management. Broad-based, scientifically sound information obtained through natural resource monitoring will have multiple applications for management decision-making, research, education, and the promotion of public understanding of park resources.

1.2 Legislation, Policy and Guidance

National Park managers are directed by federal law and National Park Service policies and guidance to know the status, trends and condition of natural resources under their stewardship in order to fulfill the NPS mission of conserving parks unimpaired. The mission of the National Park Service (National Park Service Organic Act, 1916) is:

> "*...to promote and regulate the use of the Federal areas known as national parks, monuments, and reservations hereinafter specified by such means and measures as conform to the fundamental purposes of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations*".

Congress strengthened the National Park Service's protective function, and provided language important to recent decisions about resource impairment, when it amended the Organic Act in 1978 to state that *"the protection, management, and administration of these areas shall be conducted in light of the high public value and integrity of the National Park System and shall not be exercised in derogation of the values and purposes for which these various areas have been established…"*.

More recently, the National Parks Omnibus Management Act of 1998 established the framework for fully integrating natural resource monitoring and other science activities into the management processes of the National Park System. The Act charges the Secretary of the Interior to "*continually improve the ability of the National Park Service to provide state-of-the-art management, protection, and interpretation of and research on the resources of the National Park System*", and to *"… assure the full and proper utilization of the results of scientific studies for park management decisions*." Section 5934 of the Act requires the Secretary of the Interior to develop a program of "*inventory and monitoring of National Park System resources to establish baseline information and to provide information on the long-term trends in the condition of National Park System resources*."

Congress reinforced the message of the National Parks Omnibus Management Act of 1998 in its text of the FY 2000 Appropriations bill:

> *"The Committee applauds the Service for recognizing that the preservation of the diverse natural elements and the great scenic beauty of America's national parks and other units should be as high a priority in the Service as providing visitor services. A major part of protecting those resources is knowing what they are, where they are, how they interact with their environment and what condition they are in. This involves a serious commitment from the leadership of the National Park Service to insist that the superintendents carry out a systematic, consistent,*

professional inventory and monitoring program, along with other scientific activities, that is regularly updated to ensure that the Service makes sound resource decisions based on sound scientific data."

The 2001 NPS Management Policies updated previous policy and specifically directed the Service to inventory and monitor natural systems:

"Natural systems in the national park system, and the human influences upon them, will be monitored to detect change. The Service will use the results of monitoring and research to understand the detected change and to develop appropriate management actions".

Further, *"The Service will:*

- *Identify, acquire, and interpret needed inventory, monitoring, and research, including applicable traditional knowledge, to obtain information and data that will help park managers accomplish park management objectives provided for in law and planning documents;*
- *Define, assemble, and synthesize comprehensive baseline inventory data describing the natural resources under its stewardship, and identify the processes that influence those resources;*
- *Use qualitative and quantitative techniques to monitor key aspects of resources and processes at regular intervals;*
- *Analyze the resulting information to detect or predict changes, including interrelationships with visitor carrying capacities, that may require management intervention, and to provide reference points for comparison with other environments and time frames;*
- *Use the resulting information to maintain-and, where necessary, restore-the integrity of natural systems" (2001 NPS Management Policies).*

Additional statutes provide legal direction for expending funds to determine the condition of natural resources in parks and specifically guide the natural resource management of network parks, including:

- Taylor Grazing Act 1934;
- Fish and Wildlife Coordination Acts, 1958 and 1980;
- Wilderness Act 1964;
- National Historic Preservation Act 1966;
- National Environmental Policy Act of 1969
- Clean Water Act 1972, amended 1977, 1987;
- Endangered Species Act 1973, amended 1982
- Migratory Bird Treaty Act, 1974;
- Forest and Rangeland Renewable Resources Planning Acts of 1974 and 1976
- Mining in the Parks Act 1976;
- American Indian Religious Freedom Act 1978;
- Archaeological Resources Protection Act 1979;
- Federal Cave Resources Protection Act 1988;
- Clean Air Act, amended 1990.

1.3 Formation and Planning Approach of the Eastern Rivers and Mountains Network

The National Park Service mission, to preserve, protect, and maintain the health of park ecosystems for the enjoyment of future generations, relies upon access to science-based information regarding the status and trends of ecosystem health. Parks have a critical need to know the condition of natural resources in order to meet the basic goal of preservation. To address this need, the NPS implemented a new strategy to conduct a service wide Inventory and Monitoring (I&M) program. There are three major components of the I&M strategy: (1) completion of basic resource inventories; (2) creation of prototype long-term ecological monitoring programs; and (3) implementation of operational monitoring of critical parameters.

As part of the strategy to achieve the goals and objectives of the I&M program, the National Park Service grouped parks into 32 networks. Networks comprise parks having similar resources and management issues, and represent an organized approach to reduce costs, ensure consistent products, and increase information exchange. One of these 32 networks includes nine National Park Service units in Pennsylvania, New York, New Jersey, and West Virginia and is referred to as the Eastern Rivers and Mountains Network (ERMN). Each network has completed a plan to conduct biological inventories (component 1 above), and has now moved on to designing an integrated monitoring program (planning for component 3 above), however the ERMN does not include a "prototype park" (component 2 above).

The Eastern Rivers and Mountains Network is following the basic approach to designing a monitoring program (component 3 of the I&M strategy) described in detail in the Recommended Approach for Developing a Network Monitoring Program which contains the following seven steps (http://science.nature.nps.gov/im/monitor/approach):

1. Form a network Board of Directors and a Science Advisory Committee
2. Summarize existing data and understanding
3. Prepare for and hold a scoping workshop
4. Write a report on the workshop and have it widely reviewed
5. Hold meetings to decide on priorities and implementation approaches
6. Draft the monitoring strategy
7. Have the monitoring strategy reviewed and approved

These steps are incorporated into a three-phase planning and design process that has been established for the NPS I&M program. Phase 1 of the process (described in this report) involves steps one and two: begin the process of identifying, evaluating, and synthesizing existing data; developing draft conceptual ecological models; defining draft monitoring goals, objectives and questions; and completing other background work that must be done before the initial selection of ecological indicators (i.e., Step 3: Vital Signs Selection Scoping Workshop). The timeline for completing all seven steps is illustrated in table 1.

Table 1. Overall timeline for the Eastern Rivers and Mountains Network to complete the entire three phase planning and design process to develop a monitoring program.

ACTIVITY	FY2002	FY2003	FY2004	FY2005	FY2006	FY2007
Data and information cataloguing						
Inventories to support monitoring						
Park and Network scoping workshops						
Conceptual modeling						
Indicator selection and prioritization						
Protocol development, monitoring design						
Monitoring Plan Due Dates Phase 1, 2, 3			Phase 1 Oct. 04	Phase 2 Oct. 05		Phase 3 Dec. 06

In FY 2002, the Eastern Rivers and Mountains Network received initial funding to conduct baseline inventories at parks that support potential monitoring (component 1 of the I&M strategy). These inventories continue today with the last year of funding for inventories coming in FY2005. In the fall of 2002, the first Board of Directors Meeting took place. The seven-member Board of Directors consists of five superintendents representing the park units, the Northeast Region I&M Coordinator, Beth Johnson, and one of the Northeast Region's Chief Scientists, John Karish. In FY 2003, the Eastern Rivers and Mountains Network received initial funding to support the development of the monitoring program. The Board agreed on University Park, PA (Pennsylvania State University—School of Forest Resources) as a duty station for network staff. In August 2003, Matthew Marshall was hired as Network Coordinator and Nathan Piekielek was hired as Network Data Manager in September, 2003. A network Science Advisory Committee is also being organized to assist and oversee program development. This committee currently consists of seven members, chaired by the ERMN Network Coordinator. The seven members include Northeast Region I&M Coordinator, Beth Johnson; one of the Northeast Region's Chief Scientists, John Karish; Northeast Region Hydrologist, Alan Ellsworth; Northeast/National Capital Region Aquatic Ecologist, Jeff Runde; Tonnie Maniero, NPS Air Resources Division, a USGS biometrician / ecologist, Duane Diefenbach, and the network Coordinator, Matt Marshall. Additional members will be added as the program develops and needed areas of expertise are identified.

Summarizing Existing Data and Understanding

The second step in developing the monitoring program is to identify and summarize existing data on natural resources, park management issues and concerns, and threats for each of the parks in the network. This is being accomplished in the ERMN in several steps. Beginning in 1999 all existing information on vertebrates and vascular plants occurring in the ERMN was compiled. Species checklists, research, technical reports, management plans, wildlife observation cards, collection permits, and voucher specimen information from both museum and university collections were gathered and entered into NPSpecies and NatureBib (two of the servicewide I&M databases). This process of data summarization which began in 1999 remains ongoing. The Northeast Region's scientific librarian, hired to gather all bibliographic information for parks in the Northeast, is visiting each park to individually search their libraries and work with park staff to compile information and update the NatureBib database. Research Associates from Penn State University, as well as taxa experts, continue to work on the Network's NPSpecies database by adding new species and voucher specimen records, as well as on the continual process of database maintenance to ensure quality and accuracy. The data mining and database updating process is, and will continue to be, ongoing for a number of years.

The next step involved obtaining, reading and reviewing all of the available documents pertaining to resource management (i.e. Resource Management Plans, General Management Plans, Strategic Plans, Annual Performance Plans, published scientific literature, relevant websites, etc.) for each park unit. This was done by the Network Coordinator and by a Penn State Research Associate (Jennifer DeCecco).

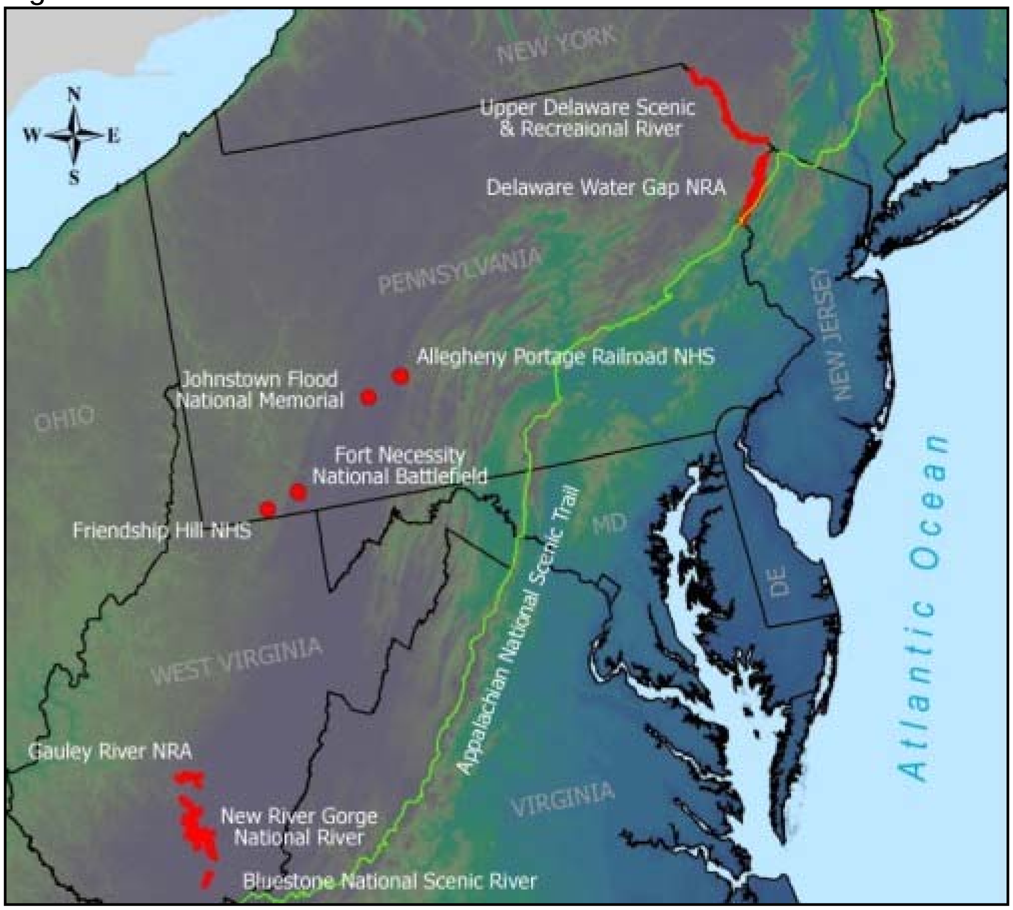
In addition, visits to each of the parks were scheduled beginning in the fall of 2003 to meet with Natural Resource Managers and other staff to discuss priority park natural resources, threats to the resources, dominant management issues, as well as current monitoring programs. A summary of these workshops and scoping meetings is presented in Appendix G.

The information gathered from this data-mining effort, literature review, and scoping meetings are the primary means by which the following summaries and Appendices A-D were developed. These summaries should be considered a work in progress.

1.4 General Overview of Eastern Rivers and Mountains Network Parks

The Eastern Rivers and Mountains Network includes nine parks located in four states: New York, New Jersey, Pennsylvania, and West Virginia (Figure 1 and Table 1). A relatively small segment of the Appalachian Trail in PA and NJ is included in the network, but trail activities associated with the Inventory and Monitoring Program are currently coordinated by the Northeast Temperate Network. The smallest of the parks in the network is Johnstown Flood National Memorial (JOFL) at 164 acres and the largest is the Upper Delaware National Scenic and Recreational River (UPDE) with over 75,000 acres in the authorized legislative boundary. The four Pennsylvania parks were created to protect and interpret cultural resources and include two National Historic Sites (FRHI and ALPO), one National Battlefield site (FONE), and one National Memorial (JOFL).

Figure 1. Location of Eastern Rivers and Mountains Network Parks.



Although these are small parks with a focus on cultural resources, each of the parks contain valuable natural resources, including rare or regionally important plant and animal species and habitats. Delaware Water Gap National Recreation Area (DEWA) receives the largest number of visitors each year due primarily to its proximity to major metropolitan areas of the Northeast. Forty miles of the middle Delaware River within the park is preserved through the Wild and Scenic Rivers Act of 1968 and is part of the last remaining undammed river in the eastern United States. DEWA also contains a diversity of regionally and globally significant terrestrial resources. The Upper Delaware National Scenic and Recreational River (UPDE) is located upstream of DEWA and was created through the same Wild and Scenic Rivers legislation. Because the park owns only a very small amount of land around its administrative buildings, a truly cooperative effort is necessary to manage natural resources at UPDE. Both DEWA and UPDE are important recreation areas for boaters, anglers and water-based recreational activities. The New River Gorge National River (NERI), possibly one of the oldest rivers in the world, and the Gauley River National Recreation Area (GARI), which includes sections of the Meadow River, are also important destinations for water recreation. Both parks contain a vast array of unique aquatic, geologic and terrestrial resources some of which have global significance. The Bluestone National Scenic River (BLUE) was also created through Wild and Scenic Rivers designation and is used primarily by anglers, but it also has a unique set of habitat characteristics and floristic communities that represent the northern limit of their range. These river parks contain some of the most significant water resources and water-based recreational activities in the National Park system.

See Appendix A for a more in-depth discussion of the natural resources and prevalent management issues at each of the parks.

Table 1. Brief overview of the parks in the Eastern Rivers and Mountain Network.

Park Name	Park Code	State	Year est.	Yearly Visitors (FY03)	Acreage (FY03)
Allegheny Portage National Historic Site	ALPO	PA	1964	127,823	1,249
Johnstown Flood National Memorial	JOFL	PA	1964	117,179	164
Friendship Hill National Historic Site	FRHI	PA	1978	34,558	675
Fort Necessity National Battlefield	FONE	PA	1931	93,649	902
Upper Delaware Scenic and Recreational River	UPDE	PA/NY	1978	259,713	75,000
Delaware Water Gap National Recreation Area	DEWA	PA/NJ	1965	4,616,320	67,192
Bluestone National Scenic River	BLUE	WV	1988	50,384	4,310
Gauley River National Recreation Area	GARI	WV	1988	152,706	11,507
New River Gorge National River	NERI	WV	1978	1,121,416	72,189

1.5 Ecological Overview of Eastern Rivers and Mountains Network Parks

The ERMN lies within temperate latitudes, which provide a relatively mild climate with favorable growing conditions. Typical of the region, the ERMN is characterized by hot, humid summers and cold winters with moderate snowfall. The region receives roughly 30 – 50 inches of precipitation annually yet there are periodic droughts that occur principally in the summer which can have profound impacts on vegetation and aquatic systems. Similarly, periodic high precipitation events can lead to flooding along streams and large rivers.

Major habitats range from broad river floodplains to small, ephemeral streams, high mountains to deep gorges, and dry barrens to mesic forests. The broad, gently-rolling hills have rounded, usually dry-oak forested summits with gradually sloping sides of mesophytic forest that are separated by narrow valleys with well drained, rich soils. Some areas are much more rugged with steep gorges, tallus slopes, and cliff faces. The maintenance of many of these habitats is dependent upon natural disturbances such as fire, wind, flooding, landslides, ice storms, insect cycles, and occasionally hurricanes. Ecologically, these natural disturbances have played a large role in determining many of the intricate landscape patterns that characterize the ERMN both spatially and temporally.

Woodrats are scattered through steep rocky areas with large talus slopes. Timber rattlesnakes are also common in these areas. Bog turtles are found in remnant wetland complexes. Significant birds include Cerulean warbler and Swainson's thrush in floodplain corridors and shrubland and grassland nesting birds in old fields, grasslands, and other landscapes. Many other rare and significant animals that characterize the ERMN are associated with the major river systems which provide a diversity of high- and low-energy aquatic habitats. A high diversity of mussels, fish and dragonflies occur across the ERMN from the Delaware and Chesapeake, to the Ohio River drainage. The ERMN is home to a diverse assemblage of plant communities, some of global significance, and numerous state listed species.

The region was settled by Europeans soon after their arrival on the eastern seaboard. The following century of widespread and intensive natural resource extraction and manipulation significantly influenced the distribution and composition of the region's contemporary landscapes and natural communities. The landscape is suitable to timber production on the hills and small farm agriculture in the lowlands. Vast coal deposits are also found throughout much of the area and have been the subject of widespread exploitation throughout modern history. More than 90% of the original forest cover was removed and only a few patches of *old growth* forests remains in remote and inaccessible mountain coves and ravines. With the decline of the small farm agriculture characteristic of the region, which began at the turn of the last century, a substantial land area is returning to forest. Forest pathogens have also dramatically modified the forest of the ERMN. American chestnut historically found throughout the region, has been nearly eliminated. American beech is dominant in many forested areas and has been significantly impacted by Beech bark disease. Gypsy moths reduce oak vigor and during severe prolonged outbreaks may kill oaks throughout the region. Sugar maples are also in decline. Deer overpopulation has also impacted forests in the ERMN.

1.6 Natural Resource Significance of Eastern Rivers and Mountains Network Parks

Significant natural resources were grouped into four categories as they pertain to the enabling legislation of the park, to legal mandates or policy, for other reasons such as regional or global rarity, and as they relate to the 1993 Government Performance and Results Act. Verbal descriptions of each category follow and are also paraphrased and listed in Tables 2, 3 and 4.

Natural Resources Significant to Enabling Legislation - Four parks in the network (GARI, NERI, DEWA and UPDE) were established primarily for water-based recreation, and/or to preserve important aquatic, terrestrial and geologic resources (Table 2). For example, the enabling legislation for DEWA specifically states that the park unit be established "for the preservation of the scenic, scientific and historic features, contributing to public enjoyment of such lands and water" within the park unit.

Three of the parks (BLUE, UPDE, DEWA) contain river sections that have Wild and Scenic River designation, which contributed wholly or partly to the creation of the park. The October 1978 act, proclaims that:

Table 2. Significant natural resources summary as they pertain to the enabling legislation of the park, to legal mandates or policy, or for other reasons such as global rarity.

Park	Reason Enabling Legislation	Natural Resources Significant to Legal Mandates/Policy	Natural Resources Significant for Other Reasons
ALPO	•Preservation of Allegheny Portage Railroad trace	•state listed plant species •wetlands •migratory birds •High Quality waters	•species of special concern •Blair gap run (high quality stream) •shrubland habitat
JOFL	•Preservation of remnants of South Fork Dam	•state listed plant species •wetlands •migratory birds •303d waters	•species of special concern •shrubland habitat
FONE	•Commemoration of Battle of Fort Necessity	•federally listed species •state listed species •migratory birds •wetlands	•species of special concern •shrubland habitat
FRHI	•Preservation of the home of Albert Gallatin	•migratory birds •wetlands	•species of special concern
DEWA	•Public outdoor use and Wild and Scenic River designation	•Wild and Scenic River •federally listed species •state listed species •special protection waters •wetlands •migratory birds •Appalachian trail •Category One waters	•Hemlock ecosystems •geologic resources •globally rare ecosystems and plants •High quality streams
UPDE	•Public outdoor use and Wild and Scenic River designation	•Wild and Scenic River •federally listed species •special protection waters •migratory birds	•geologic resources •globally rare species
NERI	•Conserve and interpret outstanding natural values and objects, preserve section of free-flowing river	•migratory birds •303d waters •American Heritage River	•geologic resources •globally rare species •state rare species •very large block of mixed mesophytic forest •High quality streams
GARI	•Preserve scenic, recreational, geological, fish and wildlife resources	•federally listed species •migratory birds •303d waters	•geologic resources •globally rare species •state rare species •High quality streams
BLUE	•Public outdoor use and Wild and Scenic River designation	•federally listed species •Wild and Scenic River •migratory birds	•geologic resources •globally rare species •state rare species •High quality streams

> *…certain selected rivers of the Nation which, with their immediate environments, possess outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural or other similar values, shall be preserved in free-flowing condition, and that they and their immediate environments shall be protected for the benefit and enjoyment of present and future generations.*

The remaining four parks, located in southwestern Pennsylvania (ALPO, JOFL, FRHI and FONE), were established to preserve and interpret cultural resources, although natural resources have since become part of the current management focus. In many cases, changes to the cultural landscape also influences (both positively and negatively) the natural resources of the park. Consequently, attempts to maximize both cultural and natural resource objectives simultaneously are critical.

Natural Resources Significant to Legal Mandates/Policy - Five of the parks (DEWA, UPDE, NERI, BLUE and GARI) have at least one species that is federally endangered or threatened including one bird species (bald eagle), one mussel species (dwarf wedgemussel), one plant species (Virginia spirea), two mammal species (Indiana bat and Virginia big-eared bat), and one reptile species (bog turtle) (Table 2). All of the parks have at least one (and in many cases numerous) plant or animal species that are listed on a state endangered or threatened species list (except those in West Virginia, which does not have a state list, but species are ranked according to their state and global rarity). As biological inventories continue throughout the parks, additional rare species may be found. See Appendix B for the most current list of federally and state listed, and state and globally rare species found at each park.

Many parks also have surface waters that are designated as High Quality or Exceptional Waters (or similar designation) and receive special protection and/or require that existing beneficial uses are maintained and protected. For DEWA and UPDE, the Delaware River Basin Commission has adopted a Special Protection Designation for the Delaware River and its tributaries designed to prevent degradation in streams and rivers considered to have exceptionally high scenic, recreational, and ecological values. See below and Appendix G for park-specific water quality summaries and additional information on legal, regulatory and specially designated waters in the ERMN.

Three of the parks in the Network (UPDE, BLUE and DEWA) have National Wild and Scenic Rivers within their boundaries. According to Congress, which enacted the legislation in 1978:

> *…that certain selected rivers of the Nation which, with their immediate environments, possess outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural or other similar values, shall be preserved in free-flowing condition, and that they and their immediate environments shall be protected for the benefit and enjoyment of present and future generations. The Congress declares that the established national policy of dams and other construction at appropriate sections of the rivers of the United States needs to be complemented by a policy that would preserve other selected rivers or sections*

> *thereof in their free-flowing condition to protect the water quality of such rivers and to fulfill other vital national conservation purposes.*

While this designation does not afford protection from development or use of the river system, the implicit goal is to protect the character and integrity of the river system.

According to mandates within the Clean Water Act, if water quality standards set forth by the Environmental Protection Agency are violated, the waterbody is considered impaired and will be scheduled for Total Maximum Daily Load (TMDL) development. Each state is responsible for monitoring the waterways within their state and development of appropriate remediation. Several of the parks within the network contain waters that are listed on the state's 303(d) list of impaired waterways (see below and Appendix G).

Natural Resources Significant for Other Reasons - Many of the parks contain regionally and globally significant, and/or rare natural resources (Table 3 and Appendix B). For example, the globally significant natural resources at NERI include large, apparently stable populations of Allegheny woodrats, the rare Appalachian flatrock/riverscour plant community, and one of the largest remaining unfragmented blocks of mixed-deciduous forest in the nation. GARI, DEWA and, potentially, UPDE also contain populations of the globally rare flatrock/riverscour plant communities. NERI and DEWA also contain an abundance and diversity of breeding neotropical migratory birds (including the cerulean warbler and swainson's warbler) of potential global significance as is the abundance and diversity of salamanders at NERI. DEWA also contains a globally rare limestone fen community. The floral diversity at several network parks is of national significance and each of the parks also contain either globally rare or imperiled plant and animal species as well as state rare plant and animal species (Table 3 and Appendix B). The unique geologic features of DEWA and NERI are of national significance, and many plant and animal populations and communities (such as the bat community at NERI) are of regional significance.

Table 3. Number of globally ranked (G1-G3) species within the ERMN. Appendix B contains a complete list of state listed species of special concern and their respective rankings.

TNC Rank	#ERMN Species	Status	Description
Global 1	1	Critically Imperiled	Critically imperiled globally because of extreme rarity or because of some factor(s) making it especially vulnerable to extinction. Typically 5 or fewer occurrences or very few remaining individuals (<1,000) or acres (<2,000) or linear miles (<10).
Global 2	8	Imperiled	Imperiled globally because of rarity or because of some factor(s) making it very vulnerable to extinction or elimination. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000) or acres (2,000 to 10,000) or linear miles (10 to 50).
Global 3	30	Vulnerable	Vulnerable globally either because very rare and local throughout its range, found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extinction or elimination. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals.

The Nature Conservancy (TNC) has developed a comprehensive approach to conserve each ecoregion's most important biodiversity elements. This is done through an intensive effort to evaluate each ecoregion's most important conservation targets, establish goals for protection, and identify data gaps, threats, and key strategies. The ERMN spans 5 ecoregions (listed below), 4 of which have completed this planning effort. As part of this effort, each ecoregion has identified priority conservation areas and the targets for viable elements (species, populations, communities, etc.) within each. Not surprisingly, many of the ERMN park units are identified as priority conservation areas. As we review these ecoregional plans we will highlight the elements that were identified by TNC as another means to illustrate the regional and global significance of natural resources in the ERMN. This will be completed early in FY05.

An ecoregion is a relatively large land area, determined by factors such as geology, topography, climate, and vegetation. It is big enough to encompass natural processes – such as fire – and to capture the rangewide distribution of many representative species and communities within its boundaries, yet small enough to serve as a platform for conservation action. TNC Ecoregions were derived from the ecoregional work of Robert Bailey, U.S. Forest Service. ERMN park units fall within the following five TNC ecoregions:

1. Central Appalachians Ecoregion – ALPO/JOFL/FONE/BLUE
2. Western Allegheny Plateau Ecoregion – FRHI
3. Lower New England Ecoregion – DEWA
4. High Allegheny Plateau Ecoregion – DEWA/UPDE
5. Cumberlands and Southern Ridge and Valley Ecoregion – NERI/GARI

Natural Resources Significant to Performance Management.-Under the Government Performance and Results Act of 1993 (GPRA), the National Park Service is required to set performance goals and report on the results of those goals to better achieve their mission and communicate more effectively with Congress and the public. Each park is required to develop similar performance goals that fall within the larger NPS framework. These goals are outlined in each park's Strategic Plan and Annual Performance Plan and progress is reported in the Annual Performance Report.

The servicewide GPRA goal pertaining to Natural Resource Inventories specifically identifies the strategic objective of inventorying the resources of the parks as an initial step in protecting and preserving park resources (GPRA Goal Ib1). The servicewide long-term goal is to "acquire or develop 87% of the outstanding datasets identified in 1999 of basic natural resource inventories for all parks" based on the I&M Program's 12 basic datasets (http://science.nature.nps.gov/im/index.htm). Each year the ERMN continues to make progress towards meeting this goal.

For the purposes of the ERMN Monitoring Program, the parks' goals primarily fall within the NPS Goal Category I (Preserve Park Resources). This category includes the NPS goals of containing exotic species, improving the status of federally listed species and maintaining unimpaired water quality and restoration of disturbed lands, among others. The ERMN

Monitoring Plan will identify monitoring indicators or "Vital Signs" of the network and develop a strategy for long-term monitoring to detect trends in resource condition (GPRA Goal Ib3). The network goal is to identify Vital Signs for natural resource monitoring by October 1, 2005. Other GPRA goals specific to ERMN parks that are, or may become, relevant to the ERMN Monitoring Plan are listed in Table 4.

Table 4. GPRA goals for each park that pertain to information generated by the Inventory and Monitoring program of the Eastern Rivers and Mountains Network.

GPRA Goal	Goal #	Parks with this goal
Preserve Park Resources	Ia	ALPO, JOFL, FONE, FRHI, DEWA, UPDE, NERI, GARI, BLUE
Exotic plants contained Exotic animals contained	Ia1B Ia01B	ALPO, JOFL, FONE,FRHI, DEWA, UPDE, NERI, GARI, BLUE DEWA, NERI, GARI, BLUE
Improving federal T&E species or species of concern populations have improved status	Ia2A	DEWA, NERI, GARI, BLUE
Stable federal T&E species or species of concern populations have improved status	Ia2B	NERI, GARI, BLUE
Species of concern populations have improved status	Ia2X	FONE, FRHI, DEWA
Water quality improvement	Ia4	ALPO, FONE, FRHI, DEWA, UPDE, NERI, GARI, BLUE
Paleontological Resources	Ia9A Ia09A	DEWA NERI, GARI, BLUE
Natural resource inventories acquired or developed	Ib1; 1b01	ALPO, JOFL, FONE, FRHI, DEWA, UPDE, NERI, GARI, BLUE
Vital signs for natural resource monitoring identified	Ib3	ALPO, JOFL, FONE, FRHI, DEWA, UPDE, NERI, GARI, BLUE
Geological Resources	Ib04	DEWA

See Appendix A for a more in-depth discussion of the significant natural resources at each of the parks.

1.7 Dominant Management Issues of Eastern Rivers and Mountains Network Parks

The management concerns of parks of the Eastern Rivers and Mountains Networks are specific to the principal resources in the park and often relate directly to the significant natural resources outlined in the preceding sections. This section will address certain issues that resonate network-wide to include most, if not all, ERMN parks. It is meant to build upon (and in some cases simply summarize) the information presented above.

Five parks are dominated by large rivers (NERI, GARI, BLUE, DEWA and UPDE) and main-stem water issues are of principal concern for aquatic natural resources and human health associated with water-based recreation. Issues include adequate water flow and the frequency, timing, and duration of high and low flow events (from natural flow to dam releases to catastrophic flooding); significant problems with treated and untreated sewage; acid mine drainage from abandoned mines and associated mining spoils; altered water chemistry from a variety of point and non-point sources; invasive exotic species; and the potential for a catastrophic chemical spill from neighboring highway and railway systems. These issues are complicated by the fact that the drainage area for these rivers is very large with the majority of the contributing land area falling outside park property. These "bottom-of-the-watershed" parks engage, and must continue to engage, in multi-agency, multi-stake holder, regional efforts for effective management of their water resources.

Water quality issues in ERMN parks are not limited to main-stem Rivers. Many parks are faced with water issues associated with smaller tributaries and headwater streams as well. Many of the issues are the same as for the main-stem Rivers, yet are on a smaller scale and, therefore, somewhat more directly tangible to park-based management. Still, because many of these parks were generally designated around a river (and are narrow and linear in shape); the headwaters of almost all tributaries and streams fall outside of park property. What's more, headwater areas often make up more than two-thirds of the land area of a drainage network. As such, headwater stream water quality is directly tied to land-use surrounding the park units. The dominant issue facing all parks, albeit at different levels of urgency, is development pressure and the adverse ecological effects that come with it. Because many of the ERMN parks are within a few hours' drive of growing metropolitan areas such as New York, Washington, Baltimore, Pittsburgh, and Philadelphia, landscapes surrounding parks are being increasingly fragmented by first and second home development. Most pressing is the construction of primary and secondary homes (and associated infrastructure) around DEWA and UPDE due to the proximity of metropolitan New York and New Jersey. Land use changes associated with low density residential development occurring around these two parks is the greatest threat to tributary water quality, and therefore a dominant threat to main-stem water quality. This issue is also of concern at the four PA parks and will be an increasingly important issue at NERI, GARI, and BLUE as development pressure being driven by outdoor recreational enthusiasts and vacation home developers, mounts. In the meantime, tributary stream water quality at NERI, GARI and BLUE is significantly affected by a lack of adequate sewage and septic facilities in West Virginia creating a human as well as natural resource threat. Again, local and regional involvement and cooperation is required to address these issues.

Terrestrial issues are somewhat more tractable to park-based management since a focus can be placed on lands within the park boundary. Yet again, many issues emanate from outside the park including outbreaks of exotic pests such as dogwood anthracnose, beech bark disease, gypsy moth, and hemlock wooly adelgid. Overbrowsing by deer is also a problem at many of the parks and has the potential to negatively affect forest regeneration and the viability and persistence of many rare plant species. Although many of the larger ERMN parks do allow hunting within their borders, it is impossible to regulate movement of deer in and out of the parks. Also of regional significance is the maintenance of large unbroken blocks of forested habitat. Many of these parks have significant forested areas that may only maintain their significance as part of a much larger forested landscape. Issues such as timber harvesting and development pressure outside the park are relevant in this context as well.

Many of these parks are mandated to maintain a variety of "open" spaces for cultural interpretation and other reasons. These areas range from active agricultural fields and fallow fields to grasslands and shrublands. Management of these areas has great potential to meld cultural objectives with meaningful natural resource objectives. For example, grassland and shrubland birds and butterflies are abundant in many of these areas and may sustain viable populations with only slight modifications to cultural management prescriptions.

Finally, for parks such as DEWA and NERI which have over 1 million visitors each year, impacts from recreational uses is also a concern. Both NERI and GARI are popular rafting and climbing destinations, and overuse or misuse by visitors can impact rare or threatened communities and species within the park. DEWA also has the potential for negative visitor impacts since it is used extensively for day uses including, hiking, camping, hunting, fishing and road travel. Illegal use of all terrain vehicles is a recurring problem as well at several ERMN parks and warrants further attention and investigation.

See Appendix A and below for additional and more in-depth discussions of the prevalent management issues at each of the parks.

1.8 Air Quality Monitoring Considerations for the Eastern Rivers and Mountains Network

Author: Tonnie Maniero

Tonnie Maniero of the NPS Air Resources Division (ARD) conducted a synoptic overview of air quality monitoring considerations for network parks. The full report, including a draft risk assessment for foliar ozone damage across the ERMN written by Bob Kohut of Cornell University, is included as Appendix F.

The following are the conclusions from Tonnie Maniero's report:

All ERMN parks have both wet and dry deposition monitors within 80 km. Most likely, this coverage is adequate for Network park monitoring. The ERMN parks in Pennsylvania all have MDN monitors within 60 km; none of the West Virginia parks have representative wet mercury deposition monitoring.

Assessing the sensitivity of ERMN park surface waters to atmospheric deposition is confounded by impacts from acid mine drainage in many of the parks and a shortage of recent data. Given the fish consumption advisories for mercury, PCBs and chlordane in

Pennsylvania and West Virginia, the ERMN may want to consider long-term monitoring of contaminant levels in fish or other biota.

With the exception of Upper Delaware S&RR, particulate matter is monitored within 35 km of all ERMN parks. IMPROVE sites are located within 120 km of all Network parks. This coverage is likely adequate for assessing trends in regional visibility. If visibility impairment is a particular concern for any Network park, the ERMN may want to consider installing a digital camera to record and interpret visibility conditions.

With the exception of Upper Delaware S&RR, all ERMN parks have an ozone monitor within 35 km. The ERMN may want to consider installing a portable ozone monitor in parks where nearby monitors or the interpolated Air Atlas ozone estimates may not be representative of park conditions. It would be useful to document ozone concentrations at Upper Delaware S&RR, since the area is designated nonattainment for the 1-hour NAAQS, but EPA is proposing to designate the area attainment for the 8-hour NAAQS.

The ozone injury risk assessments funded by the NPS ARD indicate a moderate to high risk of ozone injury of sensitive vegetation in all ERMN parks. The Network may want to consider conducting foliar injury surveys in ERMN parks.

1.9 Water Quality Summary for Eastern Rivers and Mountains Network Parks

Authors: Scott Sheeder, Barry Evans, and Ken Corradini
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Water is a major natural resource of the nine ERMN parks, and NPS mandates clearly state the need to protect water resources. The NPS Strategic Plan 2001-2005 provides goals and guidelines for water quality. In the Omnibus Management Act of 1998, Congress required that park managers provide a “program of inventory and monitoring of the National Park System resources.”

This report was prepared to meet the policy and regulatory portion of the water resource information and assessment needs of the Eastern Rivers and Mountains Network (ERMN). Water quality standards of the four network states—Pennsylvania, West Virginia, New York and New Jersey—were reviewed and summarized. Other materials reviewed include park “Baseline Water Quality Data Inventory and Analysis” reports (a.k.a Horizon Reports), current (2004) state lists of impaired water bodies (303(d) lists), current data (Sept. 2004) retrieved from STORET, etc. As part of these reports, information pertaining to site characteristics, past and current water quality problems, existing water quality monitoring stations and stream gages, and past and current water quality monitoring studies were summarized.

A Brief synopsis of each of the reports is provided below and in Table 5 with the full report for each Park presented in Appendix G.

The primary conclusions of this assessment are:

- Surface waters within the West Virginia and Delaware River National Parks have been impaired by fecal coli form bacteria. Short-circuiting and/or absent sewage treatment systems are the likely cause of this impairment.
- Acid mine drainage has impaired waters within the West Virginia National Parks, JOFL, and FRHI.
- The Delaware River National Parks have a human health fish consumption advisory, and are listed on the PA 303d list for mercury and PCB contamination. These constituents been identified in fish tissue, and do not imply elevated concentrations in the water column.
- Very limited water quality information is available for ALPO, FONE, JOFL, and FRHI.

Table 5. Summary of ERMN Water Quality based on 2004 assessment data.

Park Code	Miles of Rivers and Streams	303(d) listed Streams (No.)	Impaired Length (stream-mi)	Criteria Affected	Cause	High Quality Streams (No.)	High Quality Miles (stream-mi)
DEWA	178.59	4	59.48	Arsenic, Benthic Macroinvertebrates, Cadmium, Chromium, Copper, Dissolved Oxygen, Dissolved Solids, Fecal Coliform, Lead, Mercury, Nickel, Nitrate, PCB, pH, Phosphorus, Selenium, Silver, Temperature, Total Suspended Solids, Unionized Ammonia, Zinc	Unknown, N/A	46 in PA 24 in NJ	66.69
UPDE	221.41	2	75.59	Mercury, PCB	Unknown	50 in PA N/A in NY*	37.71
JOFL	0.89	1	0.57	Metals, pH	Abandoned Mine Drainage	0	0
ALPO	5.25	0	0	None	None	0	0
FONE	3.72	0	0	None	None	8	3.72
FRHI	1.58	0	0	None	None	0	0
GARI	45.51	3	31.8	Aluminum (dis), Fecal Coliform, Iron, Manganese	Mine Drainage, Unknown	8	34.19
NERI	164.54	14	76.1	Aluminum (dis), CNA-Biological, Fecal Coliform, Iron, Manganese, pH	Mine Drainage, Unknown	13	83.73
BLUE	17.57	3	12.7	Fecal Coliform	Unknown	3	12.40

*New York does not have a "High Quality" designation.

Brief Park Summaries:

Bluestone National Scenic River (WV): The contributing watershed is approximately 433 mi^2 in size with roughly 17.7 miles of streams contained within the park boundary. Of the total river miles within park boundaries, 12.4 miles are designated as "high quality". Overall, surface waters within the park boundary appear to be impacted principally by bacteria and trace metals. Approximately 12.7 miles of streams within the park have been determined by the West Virginia DEP to be impaired by fecal coliform from unknown sources. Although not specifically listed, mine drainage may also be contributing to water quality problems in the park based on an analysis of recent water quality monitoring data. No TMDLs have been developed for any of the "303d-listed" waters within the park, and TMDLs for these streams are not scheduled to be completed until 2007. In anticipation of future TMDL activities, it was recommended that at least three water quality monitoring stations be established at or near the locations of older stations that have since been discontinued, and that these stations be set up to sample for fecal coliform and various mine drainage-related parameters. Currently, there are no active water quality monitoring stations and one active USGS stream gage within or near the park boundary that could be utilized in a monitoring program.

New River Gorge National River (WV): The contributing watershed is approximately 6,952 mi^2 in size with roughly 166 miles of streams contained within the park boundary. Of the total river miles within park boundaries, 84 miles are designated as "high quality". Overall, surface waters within the park boundary appear to be impacted principally by bacteria and trace metals. Approximately 73 miles of streams within the park have been determined by the West Virginia DEP to be impaired by fecal coliform, mine drainage, or to be otherwise biologically impaired due to unknown sources. No TMDLs have been developed for any of the "303d-listed" waters within the Lower New River watershed, including those within the New River Gorge NR. The West Virginia DEP plans to develop TMDLs for all waters in the park by the end of 2007, with the exception of the dissolved aluminum TMDL for the New River, which is scheduled to be completed by 2017. In anticipation of future TMDL activities, it was recommended that at least 18 water quality monitoring stations be established at or near the locations of older stations that have since been discontinued. It was suggested that most of these stations be set up to sample for fecal coliform and various mine drainage-related parameters. It was also suggested that various other stations be set up to sample for dissolved oxygen, nutrients, and sediment as well. Currently, there are no active water quality monitoring stations and 2 active USGS stream gages within or near the park boundary that could be utilized in a monitoring program.

Gauley River National Recreation Area (WV): The contributing watershed is approximately 1315 mi^2 in size with roughly 45.9 miles of streams contained within the park boundary. Of the total river miles within park boundaries, 32.2 miles are designated as "high quality". Overall, surface waters within the park boundary appear to be impacted principally by bacteria and trace metals. Approximately 31.8 miles of streams within the park have been determined by the West Virginia DEP to be impaired by fecal coliform, iron and manganese from mine drainage, and mercury and dissolved aluminum from unknown sources (most likely mine drainage). No TMDLs have been developed for any of the "303d-listed" waters within the Gauley River watershed, including those within the Gauley River NRA. Currently, the West Virginia DEP has plans to develop TMDLs for all of these impaired waters (with some exceptions) by the end of 2006. The three exceptions are the Gauley River itself, the Meadow River, and the Summersville Lake/Reservoir. The TMDLs for these three impaired waters are not scheduled to be completed until 2016. There is currently one existing water quality station located at the downstream end of the park that appears to monitor for a fairly complete suite of trace metals, algae, nutrients, acidity, pH, temperature, dissolved oxygen, specific conductance, and more recently, total suspended solids and fecal coliform. Additionally, the DEP has also established a short-term station near an older site that could be used to support any analyses done for Peter's Creek. This station is currently being used by DEP to monitor for a suite of AMD-related contaminants as well as for fecal coliform. It has been recommended that at least two more stations be established on the Gauley and Meadow Rivers. For the Gauley River, focus should be placed on monitoring contaminants related to mine drainage (e.g., Fe, Al, Mn, and pH). For the Meadow River, emphasis should be placed on monitoring pH levels. Currently, there is one active water quality monitoring station and 4 active USGS stream gages within or near the park boundary that could be utilized in a monitoring program.

Allegheny Portage Railroad National Historic Site (PA): The Allegheny Portage Railroad National Historic Site (ALPO) is actually comprised of two separate parcels. The easternmost parcel is referred to as the "Main Unit", and the westernmost parcel is referred to as the "Staple Bend Unit". The contributing watersheds are approximately 17.4 mi^2 and 179 mi^2 in size with roughly 32 miles and less than on mile of streams contained within Main Unit and Staple Bend Unit, respectively. No portions of the surface water bodies contained within park property are designated as "high quality". Overall, surface waters within the park boundary appear to be in good condition. There are no surface water bodies contained within either section of the park that are currently included on Pennsylvania's 303d list of impaired water bodies. Consequently, there are no plans to develop any TMDLs for streams within, or that flow through, the park. Water quality data collected in the 1990s, however, suggest acidic deposition or mine drainage may be adversely impacting surface water conditions in the Blair Gap Run located in the main unit of the park. There are currently no long-term water quality or discharge monitoring stations located in or near the park. However, as part of a current "Phase 1" monitoring project being completed for the National Park Service by Penn State University, water quality data are being collected at various locations within the eastern section. More specifically, samples are being taken at 6 different locations along Blair Gap Run that flows through the site. Data being collected include in-stream measurements of alkalinity, pH, specific conductivity, dissolved oxygen, temperature, instantaneous stream discharge, selected toxics (e.g., cyanide and mercury), nutrients (N and P), turbidity, and fecal coliform.

Johnstown Flood National Memorial (PA): The contributing watershed is approximately 53 mi^2 in size with roughly 1 mile of streams contained within the park boundary. There are no specially designated (i.e. 'high quality') streams within the park property. Overall, the South Fork of the Little Conemaugh has been heavily impacted due to acid mine drainage upstream of the park property. Several tributaries to the South Fork of the Little

Conemaugh flowing through park property appear to be in good condition. At present, the entire length of the South Fork Little Conemaugh contained within the park has been included on Pennsylvania's 303d list of impaired water bodies. In this case, the stream has been determined to be impaired by pH and metals originating from abandoned mine drainage. While no specific data has been set, the TMDL assessment for this reach will be completed no later than 2015. There are currently no long-term water quality or discharge monitoring stations located in or near the park. However, as part of a current "Phase 1" monitoring project being completed for the National Park Service by Penn State University, water quality data are being collected at various locations within the park. More specifically, samples are being taken at five different locations along the South Fork Little Conemaugh River that flows through the site and some of its tributaries. Data being collected include in-stream measurements of alkalinity, pH, specific conductivity, dissolved oxygen, temperature, instantaneous stream discharge, selected toxics (e.g., cyanide and mercury), nutrients (N and P), turbidity, and fecal coliform

Fort Necessity National Battlefield (PA): The Fort Necessity National Battlefield (FONE) park is actually comprised of three separate parcels, including the main park area and the Jumonville Glen and Braddock's Grave units to the north. The Jumonville Glen unit contains no streams. The main park area and Braddock's Grave contain headwater tributaries of Scott's Run and Meadow Run, and Braddock Run, respectively. All of these streams (3.72 miles) are designated at high quality streams. Overall, surface waters within the park boundary appear to be in good condition. There are no surface water bodies contained within any of the three park units that are currently included on Pennsylvania's 303d list of impaired water bodies. Consequently, there are no plans to develop any TMDLs for streams within, or that flow through, the park. However, past water quality records have shown that in-stream zinc concentrations within Meadow Run downstream of the main park unit exceeded the acute freshwater criterion of 120 µg/L from 1974 through 1994. For this reason, it was recommended that a limited amount of sampling be conducted on the tributary stream that exits the main park area. In addition to zinc, other "Level 1" parameters such as alkalinity, pH, specific conductivity, dissolved oxygen, temperature, instantaneous stream discharge, nutrients (N and P), turbidity, and fecal coliform should also be collected for the purpose of assessing potential water quality problems associated with this section of the park. Currently, there are no active water quality or discharge monitoring stations within or near the park boundary that could be utilized in a monitoring program.

Friendship Hill National Historic Site (PA): The contributing watershed is approximately 1.4 mi^2 in size with roughly 1.7 miles of streams contained within the park boundary. There are no specially designated (i.e. 'high quality') streams within the park property. Overall, surface waters within the park boundary appear to be impacted principally by pH and trace metals. Neither of these streams has been assessed for biological impairment by the Pennsylvania Department of Environmental Protection. Consequently, these streams are not listed on the PA 303d list as either impaired or attaining their aquatic use designation, and there are currently no plans for TMDL development. A previous water quality assessment (Horizon report) and an analysis of current water quality data suggest that the two streams that flow through the park property have been heavily impacted by acid mine drainage. Between 1990 and 2004, water quality samples collected at sites on these two streams show pH values ranging between 2.41 and 3.54, and aluminum concentrations of 23,150 – 111,000 ug/L. For this reason it was recommended that sampling for pH and dissolved metals be conducted on both streams within the park. Additionally, NPS employees may wish to periodically contact the PA Department of Environmental Protection's Office of Water and Wastewater to check on the status of stream assessment and/or TMDL development. Currently, there are no active water quality or discharge monitoring stations within or near the park boundary that could be utilized in a monitoring program.

Delaware Water Gap National Recreation Area (PA and NJ): The contributing watershed is approximately 4167 mi^2 in size with roughly 200 miles of streams contained within the park boundary. Of the total river miles within park boundaries, 139 miles designated as "high quality" ("Outstanding National Resource" is the equivalent NJ designation). Overall, surface waters within the park boundary appear to be good quality for aquatic health and recreational uses. Approximately 60 miles of streams within the park are currently listed as impaired on the New Jersey and Pennsylvania 303d lists. The impaired water bodies, including the Delaware River, Bushkill and Dunnfield Creeks and Flat Brook listed as impaired due to nutrients, metals, organics, physical parameters (dissolved oxygen, temperature, etc.), and other factors, all of unknown origin. There is a fish consumption advisory in effect for the Delaware River, due to elevated levels of mercury and PCBs in fish tissue. None of the impaired water bodies are scheduled for TMDL assessment within the next several years. An analysis of 1990 to 2004 water quality data indicates that phosphorus, bacteria, and pH appear to be the water quality constituents of principle concern. With respect to current monitoring within the park, many discharge and water chemistry stations have been discontinued over the last decade. Currently the USGS and NPS are conducting an extensive, short-term tributary analysis within the park. Currently, there are 4 active long-term water quality monitoring stations and 6 active USGS stream gages within or near the park boundary that could be utilized in a monitoring program.

Upper Delaware Scenic and Recreational River: The contributing watershed is approximately 3,072 mi^2 in size with roughly 170 miles of streams contained within the park boundary. Of the total river miles within park boundaries, 31 miles designated as "high quality" by the State of Pennsylvania. New York does not have an equivalent designation. Overall, surface waters within the park boundary appear to be of good quality for aquatic health and recreational uses. All portions of the Delaware River mainstem, and the West Branch of the Delaware River located within the park property are listed as impaired on the Pennsylvania human health 303d list. Mercury and PCB pollution are listed as the cause of impairment. These listings are the result of a 1995 study, which found elevated levels of these pollutants in fish tissue. Currently, the state of Pennsylvania has not announced a TMDL assessment date for any sections of the impaired waters within the park. An analysis of 1990-2004 water quality data indicates that pH, fecal coliform and manganese concentrations may be adversely affecting water quality in the park. Currently, there are 4 active water quality monitoring stations and 5 active USGS stream discharge stations within or near the park boundary that could be utilized in a monitoring program.

1.10 Current Monitoring Efforts in the Eastern Rivers and Mountains Network

Each of the parks were asked about monitoring programs that are currently occurring within park boundaries. The results of this inquiry and input from ERMN staff can be found in Appendix C.

A list of national, state and university organizations with monitoring (or other relevant) programs outside or adjacent to park boundaries, or which can be viewed as potential collaborators on future monitoring programs can be found in Appendix D.

1.11 Establishing Monitoring Goals, Objectives, and Questions

The overall goal of natural resource monitoring in parks is to develop scientifically sound information on the current status and long-term trends in the composition, structure, and function of park ecosystems, and to determine how well current management practices are sustaining those ecosystems (http://www.nature.nps.gov/im/monitor/#GoalsObj).

The Eastern Rivers and Mountains Network will structure its monitoring program around these five, broad servicewide goals.

NPS Servicewide Vital Signs Monitoring Goals

1. Determine status and trends in selected indicators of the condition of park ecosystems to allow managers to make better-informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources.

2. Provide early warning of abnormal conditions of selected resources to help develop effective mitigation measures and reduce costs of management.

3. Provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other, altered environments.

4. Provide data to meet certain legal and Congressional mandates related to natural resource protection and visitor enjoyment.

5. Provide a means of measuring progress towards performance goals.

As an initial attempt at developing monitoring objectives and questions within this larger framework, the Network Coordinator has identified three general ecosystem types that are significant and relevant at the network level. Initial, broad monitoring objectives were applied to each. It is important to note that these are "proposed" and should be considered "straw-men" for further review and development at the Park, Network and Servicewide levels. The process for further development of these monitoring objectives and questions will begin with park-specific meetings and a meeting of the Science Advisory Committee (that will also include a review of this Phase I report) in the fall of 2004. These three broad ecosystem types were also chosen for the initial development of conceptual ecological models presented in Chapter 2 of this report.

These goals, objectives, questions and conceptual ecological models will be refined and further evaluated to develop potential vital signs and, eventually, prioritize and select vital signs for monitoring.

A. Large River Ecosystem Monitoring Objectives

Objective 1. Understand how large river ecosystems function including biological, physical and chemical components and their interactions.

Objective 2. Observe and understand natural variability in large river ecosystem components and how they change through time.

Objective 3. Understand how large river ecosystem components are affected by the surrounding landscape, atmospheric processes, and human interactions.

Objective 4. Understand how large river ecosystem components are affected by emerging diseases and invasive exotic plants and animals.

B. Tributary Watershed and Associated Wetlands Ecosystem Monitoring Objectives

Objective 1. Understand how tributary watershed ecosystems function including biological, physical and chemical components and their interactions.

Objective 2. Observe and understand natural variability in tributary watershed ecosystem components and how they change through time.

Objective 3. Understand how tributary watershed ecosystem components are affected by the surrounding landscape, atmospheric processes, and human interactions.

Objective 4. Understand how tributary watershed ecosystem components are affected by emerging diseases and invasive exotic plants and animals.

C. Terrestrial Ecosystem Monitoring Objectives

Objective 1. Understand how terrestrial ecosystems function including biological, physical and chemical components and their interactions.

Objective 2. Observe and understand natural variability in terrestrial ecosystem components and how they change through time.

Objective 3. Understand how terrestrial ecosystem components are affected by the surrounding landscape, atmospheric processes, and human interactions.

Objective 4. Understand how terrestrial ecosystem components are affected by emerging diseases and invasive exotic plants and animals.

Chapter 2 Conceptual Ecological Models

2.1 INTRODUCTION

The ERMN identified three dominant ecosystems (Large Rivers, Tributary Watersheds and associated Wetlands, and Terrestrial Ecosystems) for initial conceptual modeling. These models are essential for designing a scientifically credible monitoring strategy and are intended to formalize current understanding of system processes and dynamics, identify linkages of processes across disciplinary boundaries, identify the bounds and scope of the system of interest, and contribute to communication among scientists and program staff, between scientists and managers, and with the general public. These models are simplifications of complex systems that will help the NPS and its partners identify critical indicators, i.e., 'vital signs' of park ecosystems. A draft "long-list" of broad scale attributes, vital signs, and potential measures that compliments the conceptual models is presented in Appendix H.

ERMN adopted a stressor-based modeling approach. These conceptual models are not intended to explain all possible relationships or all factors that influence the ecosystem; they are intended to simplify and highlight the most relevant, influential, and important components of the system. These conceptual models will serve as discussion documents during workshops focused on selecting a list of vital signs. The conceptual models will promote communication and integration among scientists and managers from different disciplines during the vital signs selection process.

A note on the origin of ERMN conceptual model structure.-The ERMN Network Coordinator initially contacted Bill Route, Network Coordinator for the Great Lakes I&M Network, and Ken Lubinski (USGS Upper Midwest Environmental Sciences Center) about adopting and modifying their original conceptual model for large mid-western rivers (Lubinski and Route 2003). An arrangement was agreed upon whereby Matt Marshall, ERMN Network Coordinator, with guidance from Ken Lubinski, would modify this existing model to meet the needs, issues, and objectives of the ERMN Large Rivers modeling effort. As such, the ERMN Large River Model presented below is a modified version of this original model.

Further, Ken Lubinski agreed to let the ERMN adopt his "connected-colored-line" model structure for each of the ERMN Conceptual Models for consistency. We thank and acknowledge both Bill and Ken for their cooperation, help and support.

Definitions and Model Symbols

A *conceptual model* is "a synthesis of current scientific understanding, field observation, and professional judgment concerning an ecological system."

Drivers can be either anthropogenic or naturally occurring and are major forces of change. Examples include human development, climate, fire cycles, hydrologic cycles, and natural disturbance events (e.g., droughts, floods, lightening-caused fires) that have large scale influences on the attributes of natural systems.

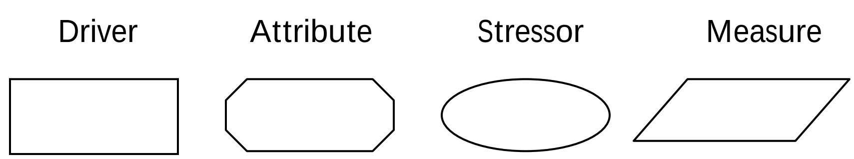
Stressors are physical, chemical, or biological perturbations to a system that are either foreign to that system or natural to the system, but occur at an excessive or deficient level. Stressors cause significant changes in the ecological components, patterns, and processes in natural systems. Examples include air pollution, water pollution, water withdrawal, pesticide use, timber and game harvest, and land-use change. They act together with drivers on ecosystem attributes.

Attributes are any living or nonliving environmental feature or process that can be measured or estimated to provide insights into the state of the ecosystem. The term *indicator* is reserved for a subset of attributes that is particularly information-rich in the sense that their values are somehow indicative of the quality, health, or integrity of the larger ecological system. Indicators are a selected subset of the physical, chemical, and biological elements and processes of natural systems that are selected to represent the overall health or condition of the system, known or hypothesized effects of stressors, or elements that have important human values.

Ecological effects are the physical, chemical, biological, or functional responses of ecosystem attributes to drivers and stressors.

Measures are the specific variables used to quantify the condition or state of an attribute or indicator. These are specified in definitive sampling protocols. For example, stream acidity may be the indicator; pH units are the measure.

Model symbols help depict various components of conceptual models and the symbols below have been consistently applied in the ERMN models.



Vital Sign, as used by NPS, is synonymous with indicator. Vital signs are intended to track changes in a subset of park resources and processes that are determined to be the most significant indicators of ecological condition.

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Lubinski, K. S. and Route, B. 2003. Large River Conceptual Model. *In* Phase 1 Report: Progress Toward Designing A Long-Term Ecological Monitoring Program. Great Lakes Inventory & Monitoring Network, US Department of Interior, National Park Service.

2.2 Large River Conceptual Model

Model Leads

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Introduction

The purpose of this report is to present a brief scientific description of large river ecosystems; their essential characteristics and attributes (i.e., communities, habitats, species and processes) and how they interact with each other; the ecological services that large rivers provide; and the connections between all of these things and the natural and anthropogenic drivers that affect them at different spatial scales.

The description is accomplished by using a diagrammatic conceptual modeling approach that focuses on stressors (i.e., mechanisms of change caused by either natural or anthropogenic drivers) that are either foreign to the system or that occur outside of what we interpret as their natural range of variation. The model is intended to be a synthesis of current scientific understanding, field observations, and professional judgments regarding large river ecosystems.

The report is intended to assist the National Park Service (NPS) in developing monitoring plans for five riverine Park Units that fall within the Eastern Rivers and Mountains Network:

The Upper Delaware Scenic and Recreational River (UPDE) which protects a 73 mile segment of the Delaware River between Pennsylvania and New York.

The Delaware Water Gap National Recreation Area (DEWA) which protects a 40 mile segment of the Delaware River between Pennsylvania and New Jersey.

The New River Gorge National River (NERI) which protects a 53 mile segment of the New River in West Virginia.

The Gauley River National Recreation Area (GARI) which protects a 25 mile segment of the Gauley River and a 6 mile section of the Meadow River in West Virginia.

and

The Bluestone National Scenic River (BLUE) which protects an 11 mile segment of the Bluestone River in West Virginia.

In addition, the report includes suggestions about vital signs of large river ecosystem health (Karr and Chu 1999; Karr 1999) that can be considered potential focal points of future monitoring programs at the riverine Park Units.

This report is not, however, intended to present regional details about the riverine Park Units or to rank the drivers and stressors by their level of importance. The river fundamentals presented here will be considered and merged with local information at a future workshop that focuses on the needs for, and implementation constraints to, monitoring in the Eastern Rivers and Mountains Network.

Some Key Ecological Concepts about Large Rivers

Most of the large rivers of the Eastern Rivers and Mountains Network, like their counterparts worldwide, have been altered by a variety of human activities (Welcomme 1985, Dynesius and Nilsson 1994, Galat and Frazier1996). Humans have altered the physical templates of rivers, the hydraulic dynamics of their channels and tributary networks, and the land use characteristics of their basins. On such disturbed systems, management requires the restoration of altered system features to desired levels of quality (National Research Council 1992) and the conservation of river features that still exhibit desirable conditions.

Our scientific knowledge of large river ecosystems has expanded greatly over the last three decades (Johnson et al. 1995, Lorenz et al. 1997, Ward 1998, Tockner and Stanford 2002). However, there is a great need to confirm many of our beliefs with data from rivers. The following concepts of river ecosystem structures, functions, and controlling factors are generally well accepted today by many river ecologists. Future monitoring within the riverine Park Units will probably support many of these beliefs, but we should expect to find that some of them will be incomplete. Future visits and modifications to this conceptual model will thus provide an opportunity to develop a better understanding of the class of ecosystems called large rivers.

The ecological condition of a large river depends on drivers and stressors that exist at multiple spatial scales (Frissell et al. 1986, Lubinski 1993, Naiman 1998, Ward et al. 2001, Weins 2002). Drivers that operate at larger spatial scales tend to exert control over longer temporal scales and cycles (Poff and Ward 1990, Naiman 1998). Within a basin, as rivers increase in size in the downstream direction, predictable gradients occur in the forces that shape the stream, control the substrate, and provide organic material (Vannote et al. 1980).

Large rivers tend to be located at lower elevations than smaller streams within the same basin. They also often have shallower elevation gradients than their tributaries and therefore trap more sediment and have longer water retention times. These conditions, with the exception of local areas where the channel is constricted, generally result in lower water velocities and substrates dominated by finer particles. Under natural conditions, the discharge of a river increases with distance downstream. The predictability of the flow regime of a large river is typically greater than the predictability of its smaller, flashier tributaries (Johnson et al. 1995).

Under natural conditions, the primary sources of energy in a large river, detritus, fine particulate organic material, and attached bacteria, are usually allochthanous, that is carried downstream by tributaries. The River Continuum Concept (Vannote et al. 1980) holds that local photosynthesis in large rivers is limited by turbid water. However, the presence of dams, floodplains with large backwaters, or large amounts of woody debris in a given large river reach can reset energy processes to conditions more like those that occur in moderate size streams (Ward and Stanford 1983, Junk et al. 1989, Thorp and DeLong 1994, Bayley 1995). Under these conditions, in-stream (autochthanous) energy production through photosynthesis and increased invertebrate production increases. In large rivers with substantial floodplains, annual flood pulses have been identified as perhaps the most important hydrologic feature that governs year-to-year changes in ecosystem productivity and possibly biological diversity (Junk et al 1989, Ward 1989).

Large rivers frequently exhibit distinctive reach or microhabitat characteristics that are attractive to individual or groups of species (Stalnaker et al., 1989, Montgomery and Buffington 1998, Ward 1998). Reach distinctions frequently are reflected in different vegetation patterns, community types and habitat assemblages (Lubinski 1993). Microhabitat attractions are often most clearly observed during specific life history stages, seasons, or discharge ranges. An especially important characteristic of large rivers is that conditions in their microhabitats change widely with river discharge (Reash 1999). Population changes in response to year-to-year variations in discharge are considered to be an important contributor to riverine biodiversity (Knutson and Klass 1997, Galat et al. 1998).

The flora and fauna of large rivers are adapted to and controlled in large part by the conditions discussed above. It is also important to keep in mind however, that large-scale distribution patterns of many species, terrestrial and aquatic, in the region still reflect zoo-geographic patterns established by glacial land forming processes that existed thousands of years ago.

Large rivers, within the context of either their tributary networks or even broader spatial scales, function as landscape corridors (Lubinski and Theiling 1999). In this role they provide ecological services such as removing wastes, and transporting nutrients, sediments and water itself, to systems downstream. The landscape corridor function of large rivers is of special value to migratory birds and fishes in some cases extending beyond the basin itself (as in the case of migratory bird species).

Large River Conceptual Modeling

A variety of large river models have been developed that can be considered conceptual in nature (Amoros et al. 1987, Karr 1991, Lubinski 1993, Bayley 1995, Ward 1989). Although these models share many similarities, each contains unique elements, a result, in part, of the need to use the models for different purposes. The context and desired application of a conceptual model likewise determines its size, scope, and level of complexity.

Modeling Natural Conditions

The purpose of conceptual models in development by the Eastern Rivers and Mountains Network, is to "promote communication and integration among scientists and managers from different disciplines during the vital signs selection process". Consequently, we started constructing the conceptual model by considering natural large river attributes and their drivers. Karr's (1991, 1999) view of primary stream ecosystem elements (Figure 1) served as the basis for the six attributes (biological integrity, biological interactions, channel/floodplain geomorphology, water flow, water quality, and energy flow) presented in the basic, undisturbed large river model (Figure 2). Geology, climate, and basin land cover have often been considered primary drivers of streams and river ecosystems (Bhowmik et al 1984, Resh et al. 1988). Under undisturbed conditions, each of the six attributes varies over time, responding to seasonal, annual and long-term changes in the three drivers. Water and sediment discharge regimes within the basin stream network provide the major mechanisms for the drivers to affect changes in the river attributes.

Natural disturbances, such as earthquakes, droughts or infrequent, channel-forming (i. e. one in five-hundred-year) floods, caused the attributes to depart from their 50 – 100 year range of variation (Sparks et al. 1990, Sparks et al. 1998). Native species however, being adapted to such disturbances, tended to return to pre-disturbance, system-wide population levels rapidly, even if their distribution shifted across fine spatial scales.

Definitions in use by the National Park Service distinguish between attributes and vital signs. Not all attributes are considered to be vital signs. Vital signs are defined as a subset of system attributes that is particularly information-rich and indicative of the quality, health, or integrity of the ecosystem. In the National Park Services' proposed monitoring operation, vital signs are intended to track changes in a subset of park resources and processes. Cairns et al. (1993) recognized that indicators could, in addition to functioning in trend detection, also serve in early warning and diagnostic roles. The National Park Service's emphasis on the trend detection functional role of vital signs was critical to developing the decision-making process for their selection.

Given the emphasis on trend detection, and the need to narrow the number of large river attributes to a set that could function in an operational monitoring program, we dropped two attributes, biological interactions and energy flow, from further consideration. These attributes have not been quantified extensively in large rivers, and the lack of strong data sets or routine methods for measuring these attributes makes it difficult to consider them as viable trend detectors. However, should the National Park Service consider including diagnostic and early warning functions in a comprehensive adaptive assessment and management program (Harwell et al. 1999, Walters et al. 2000, Bisbal 2001), strong arguments can be cited (Bunn et al. 1999) for finding the extra resources required to treat these attributes as vital signs.

We should also note that when resource management is the responsibility of many organizations, selection of ecosystem attributes to direct a monitoring program also requires the support of partners. Harwell et al. (1999) referred to ecosystem features that are jointly regarded as important by the scientific community and the public as "essential ecosystem characteristics". If the National Park Service develops its monitoring programs to include the information needs of outside partners, more attention will need to be directed at active public participation in identifying ecosystem values, services and conceptual model elements.

Attributes for Consideration of Vital Signs

Biological Integrity

In large rivers, native species include resident species that remain in place throughout the year and migratory species. The management of migratory species requires special attention to spatial scale, as the migration corridor function provided by the river can be vulnerable at any point along the corridor, not just at monitoring locations.

The pulsing nature of a large floodplain river, which typically floods from April through June, results in complex patterns of species habitat use patterns (Ward et al. 2002). One researcher has dubbed the floodplain, not inaccurately, as a natural time-share condominium. Large river biodiversity, though difficult to quantify because of the sampling scales involved, is frequently considered high relative to smaller streams. A few selected studies have begun to provide the data to support that perception (Knutson and Klass 1998, Shiel et al. 1998, Schiemer 1999). The tendency for larger rivers to support more fish species than smaller rivers within a stream network is well known (Welcomme 1985).

Overall riverine biodiversity has been suggested as a unifying theme for river ecology (Ward and Tockner 2001) and there has also been development of taxa specific indicators to assess ecological integrity (Schiemer 2000, Wehr and Descy 1998, Karr 1999).

Floodplain/Channel Geomorphology

This attribute refers to the physical template, aquatic and terrestrial, over which river water flows. Under natural conditions, the physical structure of any given river reach is determined by its gradient and water and sediment regimes (Montgomery and Buffington 1998). Floodplain/channel geomorphology contributes to what we generally think of as habitat, but it is a system attribute, whereas habitat is defined by the species or guild of interest. Not all large rivers have floodplains, but when floodplains are present they play an important role in sediment transport and deposition, carbon and nutrient recycling, the distribution of species, and the availability of food (Ward 1989).

Hydrology/Water Flow

Because of its ecological importance, water flow in large rivers has sometimes been referred to as a "master" variable (Richter et al. 1997, Poff et al. 1997, Galat and Lipkin 2000). Together with floodplain/channel geomorphology, it is a major determinant of where species can be found in the large river system. Water flow includes multiple variables, including discharge rate, velocity, and water level elevation.

Water Quality

By water quality, we include temperature and the natural compounds, gases and other constituents that would naturally be present in the water column of a large river. For this model, we also considered some foreign materials in river waters as aspects of water quality rather than as strictly contaminants (i.e., stressors). Key water quality variables that control ecological processes or species behavior in large rivers include temperature, dissolved oxygen, suspended and bed sediment loads, dissolved and suspended carbon, and nutrients. Water temperatures play a great role in controlling the reproductive timing and success of river fishes. Low dissolved oxygen concentrations can make certain areas of the river unsuitable for use by fish and may occasionally cause fish kills. Sediment not only plays a role in fluvial dynamics and the succession of riverine plant communities, but also controls (with plankton) the turbidity of river water, which can limit the amount of photosynthetically active radiation available to submersed plants.

Adding Anthropogenic Model Elements

After identifying natural large river attributes and drivers, and selecting vital signs from the list of attributes, we identified the anthropogenic drivers and stressors that frequently control the vital signs and the overall condition of large river ecosystems. Figure 3 displays the drivers and stressors discussed most often in the literature, as well as their perceived connections to the attributes.

Most large rivers have been altered by a relatively large number of anthropogenic drivers. Thus, it should not be surprising that Figure 3 contains ten anthropogenic drivers operating though nine stressors. Table 1 provides additional details regarding the types of processes and human activities included in driver categories.

The connections shown between the drivers, stressors and attributes in Figure 3 are intended to convey a high probability of effect in any large river. However, the relative importance of the connections may differ substantially from one reach to the next, or from one time period to another. Valuable discussions of such changes in connection strength are only possible when extensive local information about the river reach of interest is available. Such discussions are anticipated at a future National Park Service workshop.

It is also beyond the scope of this conceptual modeling exercise to present a detailed discussion of each anthropogenic driver and stressor that affects large rivers. However, the comments below regarding selected driver and stressors are worth noting because of their potential relevance to the proposed monitoring programs.

Table 1. Examples of Drivers of Large River Ecosystems.

Driver Type	Driver - Coarse Level	Driver - Fine Level
Natural	Geology	Sub-basin geology Sub-basin soils
	Climate	Precipitation episode shift Annual/seasonal precipitation Annual/seasonal solar radiation
	Basin land cover & use	Sub-basin land cover and land use
Anthropogenic	Agriculture	Nutrient and chemical cycles Sediment flows
	Rail/Truck Traffic	Invasives, run-off, toxic disasters
	Dams	Flow Patterns: volume, timing, frequency, duration
	Global warming	Increased temperature More variable weather extremes Greater floods
	Point source pollution	Industrial wastes Municipal wastes Abandoned Mine Drainage
	Structural changes – main stem	Hydropower dams Floodplain development Dredging and filling
	Structural changes – tributaries	Reservoir dams Hydropower dams Headwater development
	Resource exploitation	Fish, mussel, timber harvests mining, quarrying
	Recreation	Boating, rafting, hunting, fishing
	Urbanization	Sewage and Storm Water

Vital Sign and Stressor Measures

Figures 4 and 5, respectively, illustrate measures of fine-level attributes and stressors that are applicable to large rivers generally, and to the riverine parks in the eastern Rivers and Mountains Network specifically. These measures are proposed to begin evaluating the costs of monitoring within the Park Units. As with the earlier discussion of the relative importance of different drivers and stressors, continued dialog about vital sign and stressor measures requires more detailed knowledge of spatial heterogeneity within the Park Units. That knowledge is necessary to begin to develop an efficient and effective monitoring design that would yield scientifically valid data, and information that is relevant to management decisions.

Notes Regarding Measures

Large river ecosystems include terrestrial, aquatic and transitional communities (Junk et al. 1989, Ward et al. 2002). The selection process of native species groups for monitoring should include consideration of how these communities respond to drivers and stressors that operate at local, as well as systemic scales.

Measurement frequency should be based not only on the natural temporal variability of selected vital signs, but also on the frequency of the anticipated stressor activity. As a result, while we might anticipate that many large river assessments will be required at annual intervals, others may be more appropriate at 5-10 year intervals. Still others may be event triggered, for example, during and closely following a major flood.

Point measurements in a large river are difficult to interpret and may have little value in describing overall system condition. Some repetition and randomness in the monitoring design is necessary to allow statistical inferences to larger (meso-scale) defined areas. However, the "defined areas" must also be relevant to potential management actions.

During the anticipated future dialog on monitoring, attention should be given not only to the value of each individual measure, but to the comprehensiveness of the information that is likely to be generated by the entire suite of selected measures. The suite of measures should reflect system condition equally as well as each measure reflects the condition of an individual attribute.

Effective design of an ecosystem monitoring program should at a minimum allow for the detection of trends. Documenting causality is a much more difficult task. The conceptual model presented here suggests that many anthropogenic drivers and stressors are probably affecting the health of the riverine Park Units concurrently. Complex ecosystem responses, uncontrollable circumstances, and uncertainties can therefore be expected to prevent any future ecosystem monitoring program from providing clear cut answers to questions about causation. However, coupling a well designed monitoring program to a complimentary set of controlled studies may permit the teasing apart of some of the most important causal relationships that operate within a specific large river reach. An approach that incorporates monitoring and research to generate answers to different kinds of questions will enable managers to explain as well as describe the major changes affecting Park Unit resources.

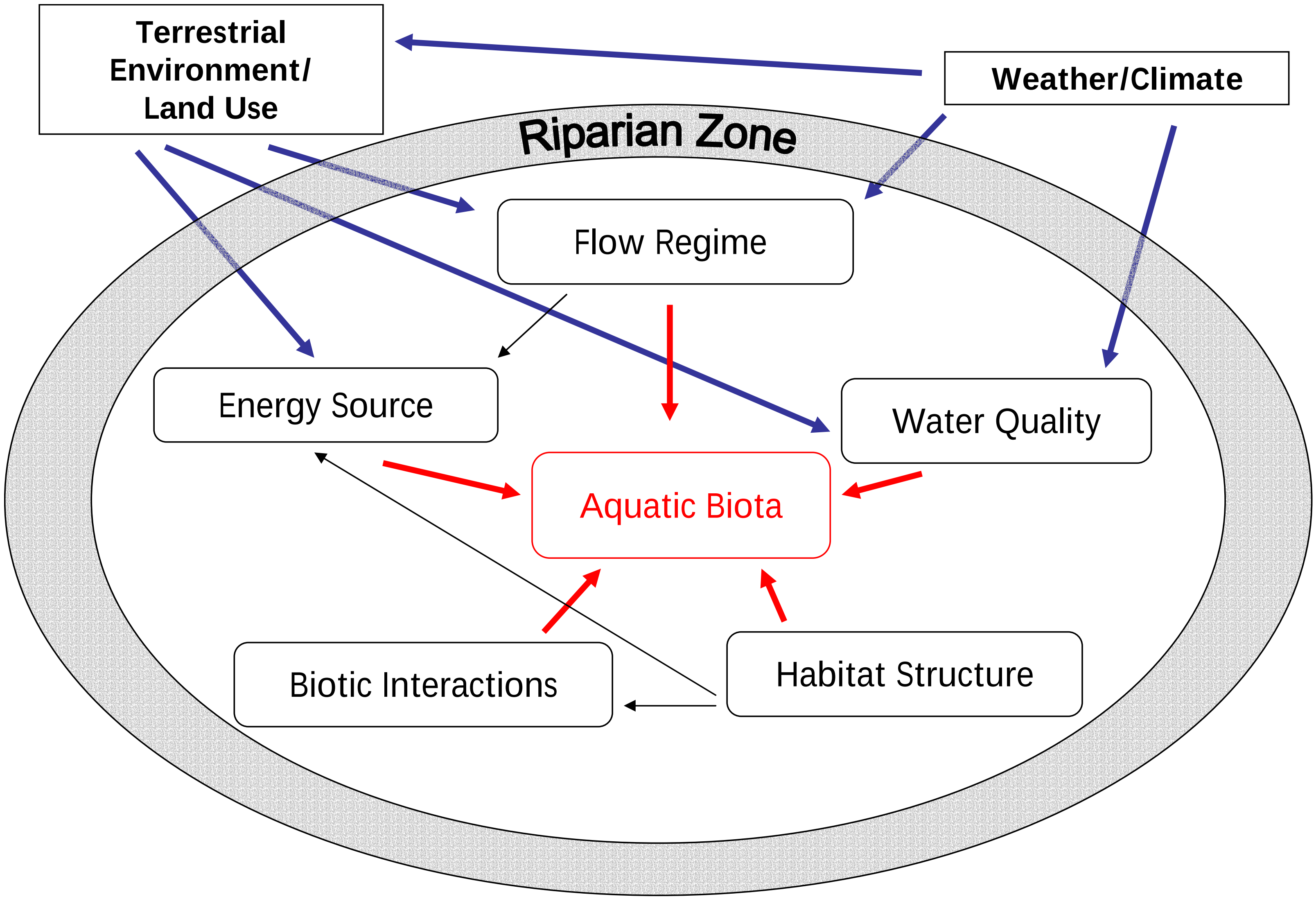

Figure 1. Basic model of a stream/river ecosystem and its elements (Karr 1991, 1999). Redrawn from Lubinksi and Route 2003.

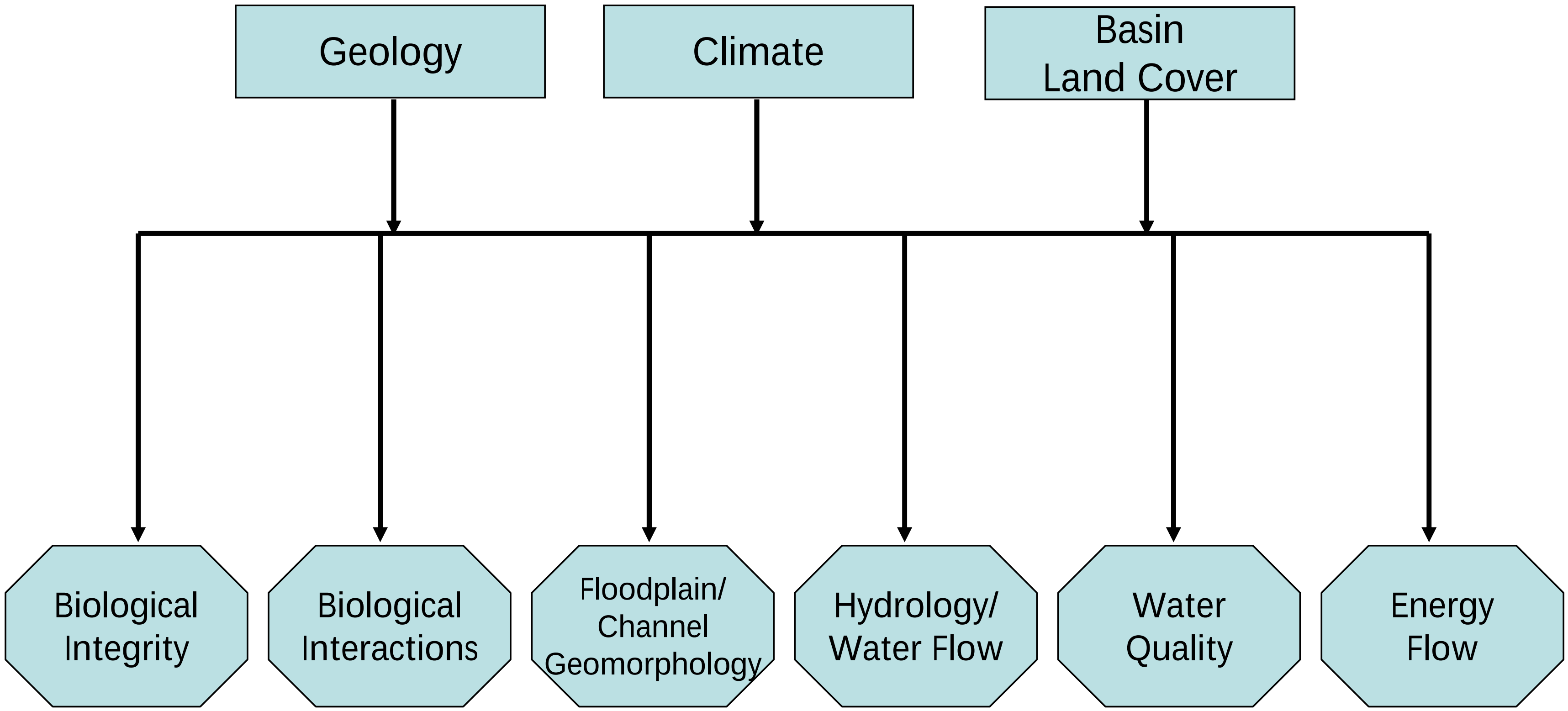

Figure 2. Large River Ecosystem Natural Drivers (rectangles) and Attributes (octogons). Redrawn from Lubinksi and Route 2003

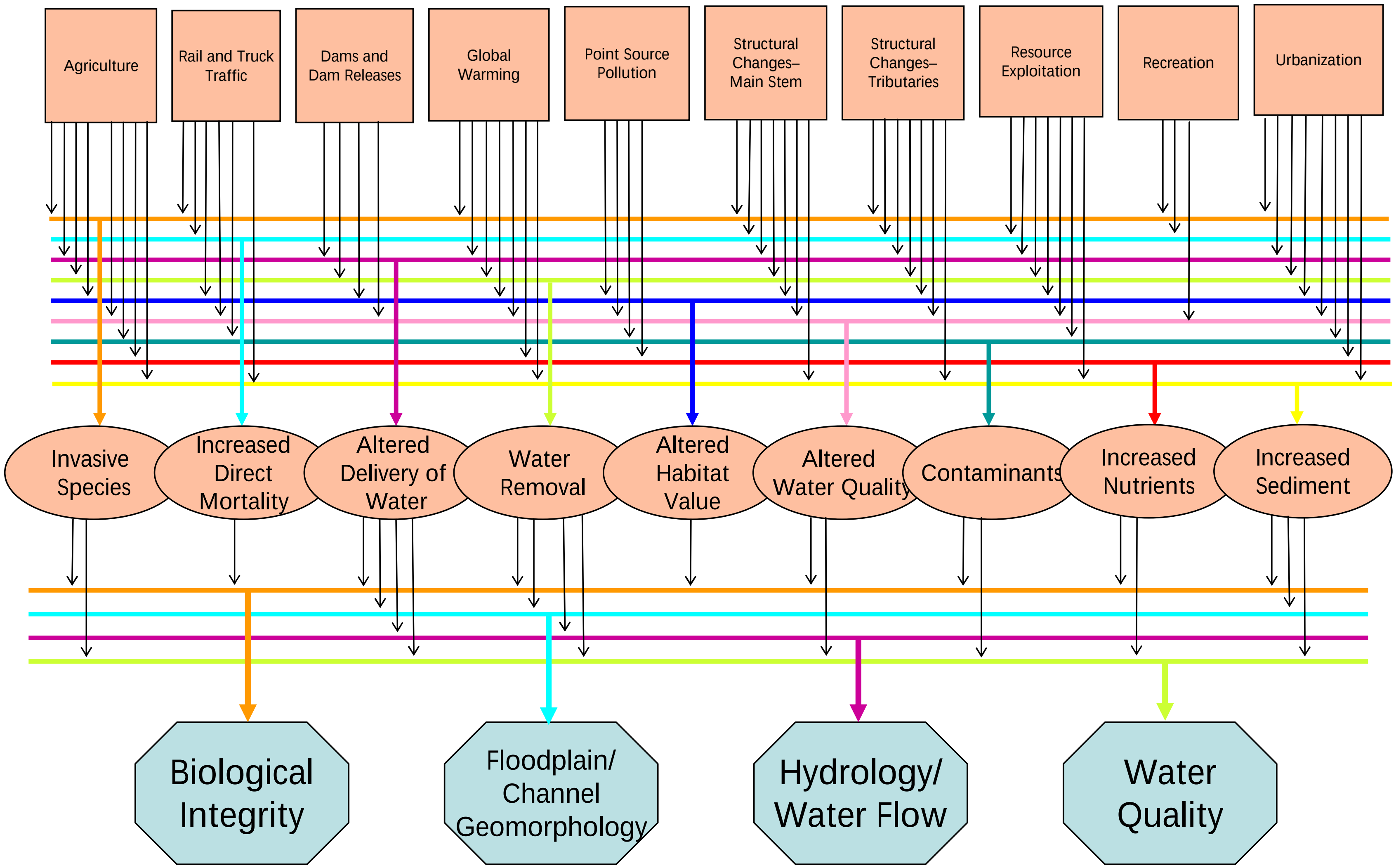

Figure 3. Large river anthropogenic drivers (rectangles), stressors (ovals), and coarse-level vital signs (octagons) for ERMN riverine park units. Each vital sign and stressor is represented by a thick, colored line. Connections (probable causal linkages) between drivers and stressors, and between stressors and vital signs, are represented by thin vertical arrows.

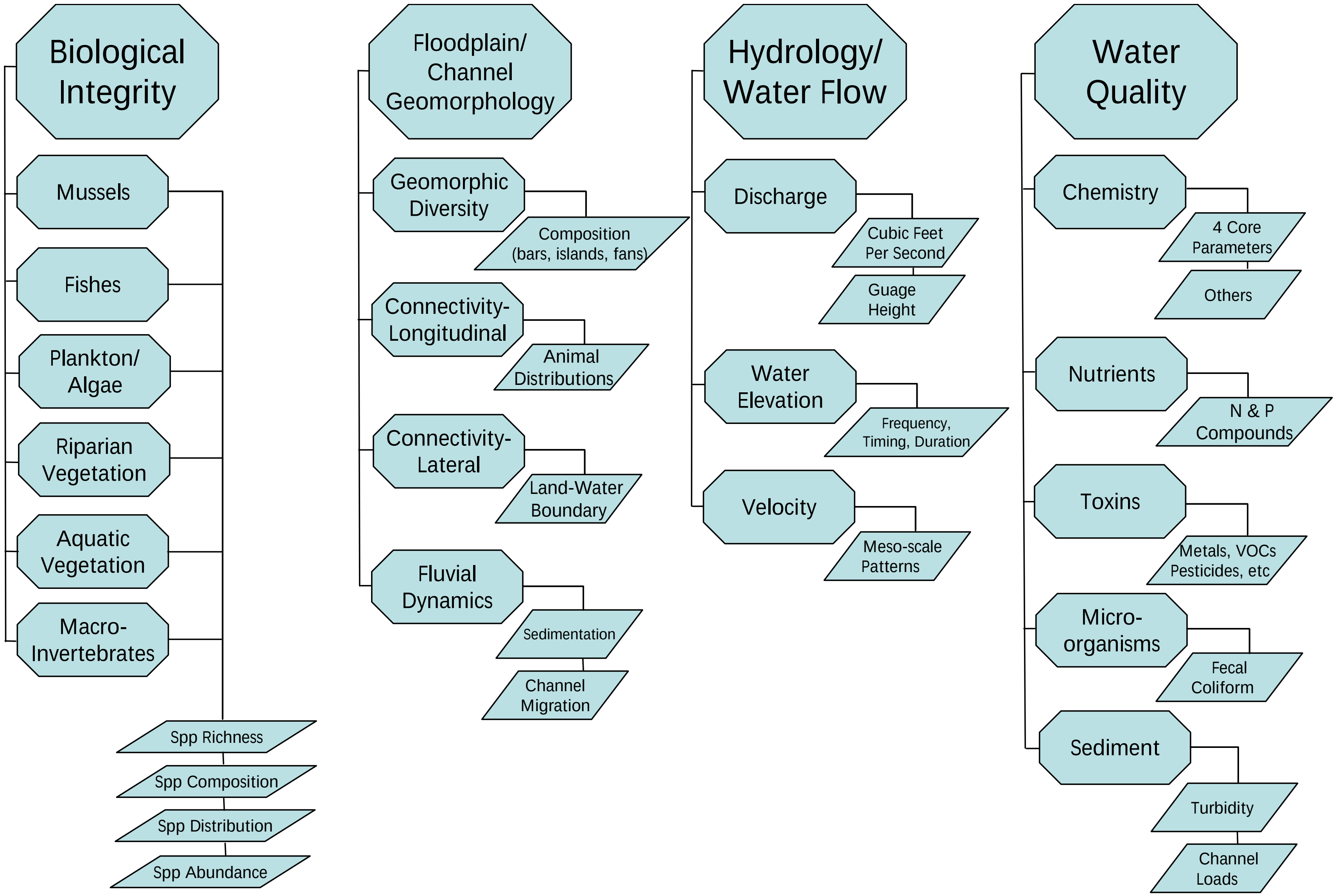

Figure 4. Large River Vital Signs and Potential Measures for ERMN riverine park units.

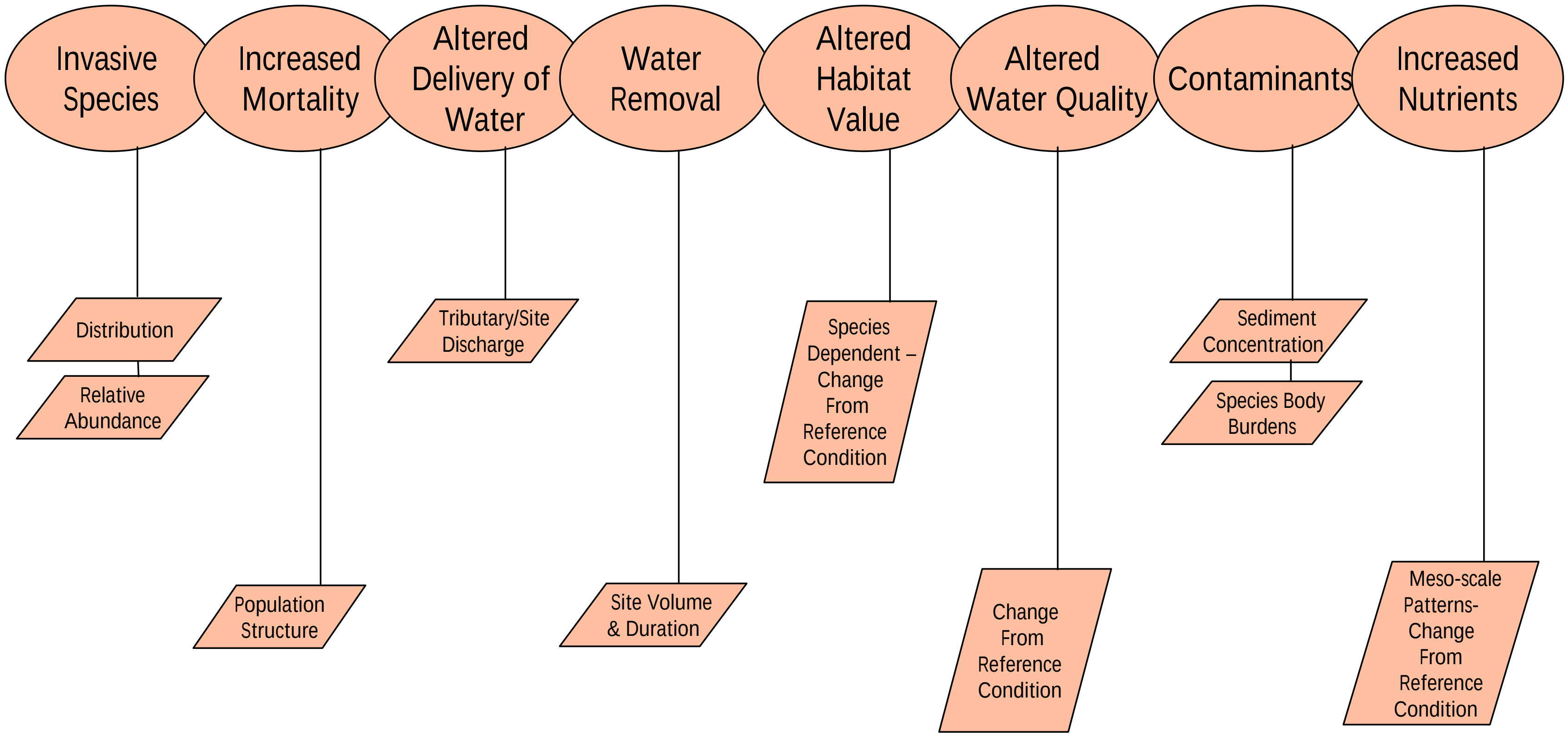

Figure 5. Stressor Measures for ERMN riverine park units.

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2.3 Tributary Watersheds and associated Wetlands and Riparian Areas Model

Model Lead

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Introduction

The importance of the tributary portion of watersheds (i.e., tributary watersheds) to the overall health of aquatic ecosystems cannot be over emphasized. In the eastern U.S., tributary watersheds typically comprise about 67-75% of the contributing area of any given watershed. That is, the combined areas of terrestrial habitats, wetlands, floodplains, and headwater streams occupy two-thirds to three-quarters of the total drainage basin for larger rivers. Given this influence on downstream portions of large river watersheds, understanding the impacts of human activities on the ecological structure and function of tributary watersheds is foundational for optimizing their conservation and management.

The conceptual model presented here represents an initial attempt at portraying the diversity and complexity present in tributary watersheds. In the context of the National Park Service's Inventory and Monitoring Program, these conceptual models seek to "promote communication and integration among scientists and managers from different disciplines during the vital signs selection process". Also, as envisioned for the Eastern Rivers and Mountains Network (ERMN), this conceptual model is designed to emphasize the role of stressors in the alteration and degradation of these ecosystems.

For this purpose, tributary watersheds are defined as a stream network consisting primarily of first and second order streams (at a 1:24,000 scale, Strahler 1952), and including where appropriate "zero" order streams which represent intermittent and ephemeral channels, and third order and occasionally fourth order streams depending on relative discharge. In addition, it is essential that we move away from considering streams in isolation from their surroundings, and integrate all components of aquatic ecosystems, including the associated wetlands, floodplains, riparian corridors, and the influence of contributing terrestrial areas. This is critical to understanding and protecting tributary watersheds because these headwater portions of larger watersheds are often subjected to a wide range of stressors. What follows is a narrative and graphical model designed to integrate these features, illustrate their ecological contributions to larger watersheds, and to identify stressors that potentially alter and degrade these systems. Finally, we hope to convey a list of potential measures that could be instituted in a long-term ecological monitoring program.

Key Ecological Concepts about Tributary Watersheds

The interactive relationships among the stream, wetland, and riparian components of watersheds for different stream orders are illustrated in Figures 1a-c. A key feature of these illustrations is the relative contribution to the functioning of these systems by upstream portions of the watershed versus immediately adjacent or lateral components. First, it is useful to consider the flow of water and materials from the upper reaches of the watershed to lower reaches. Initially, waters at the watershed boundary begin to accumulate in surface and near-surface areas. Precipitation, surface runoff, and near-surface runoff (i.e., interflow) accumulate in narrow, ephemeral or intermittent channels. In addition, discharges of shallow and deep ground water may be expressed at the surface as springs or seeps, or below the surface entering directly into streams and wetlands. Such discharges generally constitute the base flow to these systems. Eventually, somewhat dependent on season, sufficient water accumulates to sustain the flow in a perennial stream. Whereas the zero-order channel tends to dry out seasonally, first order streams tend to have a persistent flow, usually in a relatively linear channel with little or no floodplain. These relatively small elements are strongly influenced by the characteristics of the adjacent riparian corridor, whether it be the amount of tree cover, type of soil, or range of stressors. These influences, separated from inputs originating upstream, can be referred to as lateral effects.

As flow increases, pool-riffle complexes develop in the widening channels of tributary streams (second to fourth order)(Forman 1995). Floodplains continue to widen as the flow transitions from tributary streams to larger rivers. In these stages, the river itself, and to some extent the adjoining floodplain, are tied more closely to the characteristics and periodicity of the flows that have accumulated from upstream reaches, and less by the activities in the riparian corridor.

When one incorporates components outside the stream channel proper into the model, complexity of the ecosystem increases. The accumulation and flow of water across the landscape coupled with the varied microtopography of these areas results in a *river mosaic* of hydrologically-derived gradients and discontinuities across the surface (Forman 1995). The wetland components of this mosaic can be referred to as a *headwater complex* (D. Wardrop, pers. comm.). Previously, wetlands were classified primarily on the dominant vegetation and hydrology (Cowardin et al. 1979; used to code the National Wetlands Inventory). More recently, the hydrogeomorphic (HGM) approach (Brinson 1993, Smith et al. 1995) has provided additional elements for classifying wetlands (i.e., water source, water dynamics, landscape position) and for comparing functions and condition across reference sites. In tributary watersheds, the most relevant HGM subclasses of wetlands are headwater floodplains, riparian depressions, and slopes, all of which can contribute to a headwater complex, and by association, to a river mosaic (Cole et al. 1997, Brooks et al. In prep.).

Tributary Watershed Conceptual Modeling

There are many conceptual models of riverine systems in the literature, variously describing the physical, chemical, and biological components (see Vannote et al. 1980, Minshall et al. 1985, Forman 1995, Rosgen 1996). It is not the intent of this document to comprehensively review these works and the plethora of papers that support and challenge these concepts, but rather to consider these concepts as they relate to monitoring the condition of tributary watersheds and the impact of stressors upon them. As the various elements are discussed, information about potential stressors is included to assist the reader in understanding their influence on ecological integrity. Figures 1-4 summarize the elements of the conceptual model, including anthropogenic drivers, stressors and coarse-level vital signs. The structure and function of these ecosystems is considered under four general headings, *Biological Integrity, Hydrology/Morphometry, Water Quality / Biogeochemistry,* and *Landscape Pattern*. Although *Energy Flow* is an attribute of some importance (Figure 1), representing the flux of materials through ecosystems, it is not considered separately in this discussion because of the difficulty of measuring these processes with rapid assessment methods.

Biological Integrity

The biological diversity of tributary watersheds in the Mid-Atlantic region has been documented reasonably well. Some taxa pertinent to the region are particularly diverse, notably salamanders, freshwater mussels, and breeding neotropical migrant songbirds. Various investigations have tallied the species and communities that are prevalent in tributary watersheds of the region (e.g., Brooks et al. 1991, Abell et al. 2000, O'Connell et al. 2000).

The maintenance of a characteristic plant community is a designated HGM function for wetlands that also relates to a variety of ecological functions in tributary watersheds such as: energy dissipation via roughness, detrital production and nutrient cycling, and biodiversity and habitat functions. The composition of vascular plant communities have long been used to characterize wetlands (Cowardin et al. 1979, Tiner 1988, Mitsch and Gosselink 2000). Plant community composition influences many ecosystem properties, such as primary productivity, nutrient cycling and hydrology (Hobbie 1992, Ainslie et al. 1999). Plant species composition plays an important role in determining soil fertility (Wedin and Tilman 1990, Hobbie 1992). Individual plant species effects on ecosystem fertility can be as important, or more important, than abiotic factors, such as climate (Hobbie 1992). Plant community composition also influences the habitat quality for invertebrate, vertebrate, and microbial communities in both wetlands and streams (Gregory et al. 1991, Norokorpi 1997, Ainslie et al. 1999).

Plant communities are highly influenced by human disturbance due to the fact that human alterations generally act as a means of establishing invasive and aggressive species. Invasive species change competitive interactions, which result in changes in species composition (Walker and Smith 1997, Woods 1997). A checklist, which includes provisions for invasive plants, has been developed to record any observed stressors on streams, wetlands, and riparian areas in the region (Brooks 2004).

Detrital biomass is an important component of wetland ecosystems and plays a role in nutrient cycling and habitat for plant and animal communities in tributary watersheds. Detrital biomass is represented by snags, down and dead woody debris, organic debris on the forest floor, and organic components of mineral soil. This has been described for wetlands in the national riverine HGM model (Brinson et al. 1995) and regional HGM models (Brooks 2004), and for Mid-Atlantic streams (Barbour et al. (1997), Boward et al. (1999). Detritus is considered an indicator of the potential decomposition and nutrient cycling rates at a site. Decomposition is generally faster in aquatic than terrestrial landscapes due to increased leaching, fragmentation and microbial activity (Shure et al. 1986). Large pieces of coarse woody debris (CWD) are processed into fine particulate organic matter (FPOM) and then further processed and incorporated into organic matter (Bilby and Likens 1979, Jones and Smock 1991). Organic material may be transported to channels or respired as CO_2 at any stage of the decomposition process (Bilby and Likens 1979, Jones and Smock 1991).

Tributary streams are important for selected fisheries, but in general, do not support the high biomass present in large rivers. The distribution and habitat of fish species was documented by Cooper (1983) and others for the region. In high gradient headwater streams, brook trout (*Salvelinus fontinalis*), various minnows (cyprinids), and sculpins (cottids) can be common. Boltz and Stauffer (1989) highlighted the fishes that are dependent in some manner on wetlands and their connectivity with streams. Although the richness and abundance of fish in tributary watersheds can be a useful indicator of condition, fish are not always present in the upper reaches of these ecosystems. In places where fish are not present in abundance, amphibian, particularly streamside salamanders, can serve as an alternate vertebrate indicator (Rocco et al. 2004).

The importance of the wetland and riparian components of tributary watersheds as habitat for wildlife communities in reasonably well documented in the Mid-Atlantic region. Profiles for various taxa are summarized in Majumdar et al. (1989), Brooks et al. (1994), and Tiner (1998).

The provision of wildlife habitat is an often cited function of wetlands and riparian areas. Yet, we seldom have resources to census a diverse wildlife community. A commonly used alternative is to assess potential wildlife use with Habitat Suitability Index (HSI) models (Morrison et al. 1992, Anderson and Gutzwiller 1994). HSI models have been used as a means to estimate the level of wetland functioning as wildlife habitat based on consistent use of 10 common species (Brooks and Prosser 1995, Brooks 2004). A similar group of 10 common vertebrates has been proposed for assessing the condition of stream and riparian corridors (Brooks unpublished).

The influence of pollutants on the biota of streams has been well documented, and forms the basis of many federal and state water quality regulations (e.g., Karr 1999, Karr and Chu 1999). In addition, the strong influence of the surrounding landscape on a wetland's or stream's ability to perform a function has become increasingly evident (e.g., Gibbs 1993, Wardrop and Brooks 1998, O'Connell et al. 2000). Connectivity among aquatic habitats has been shown to affect both faunal (e.g., Gibbs 1993) and floral communities.

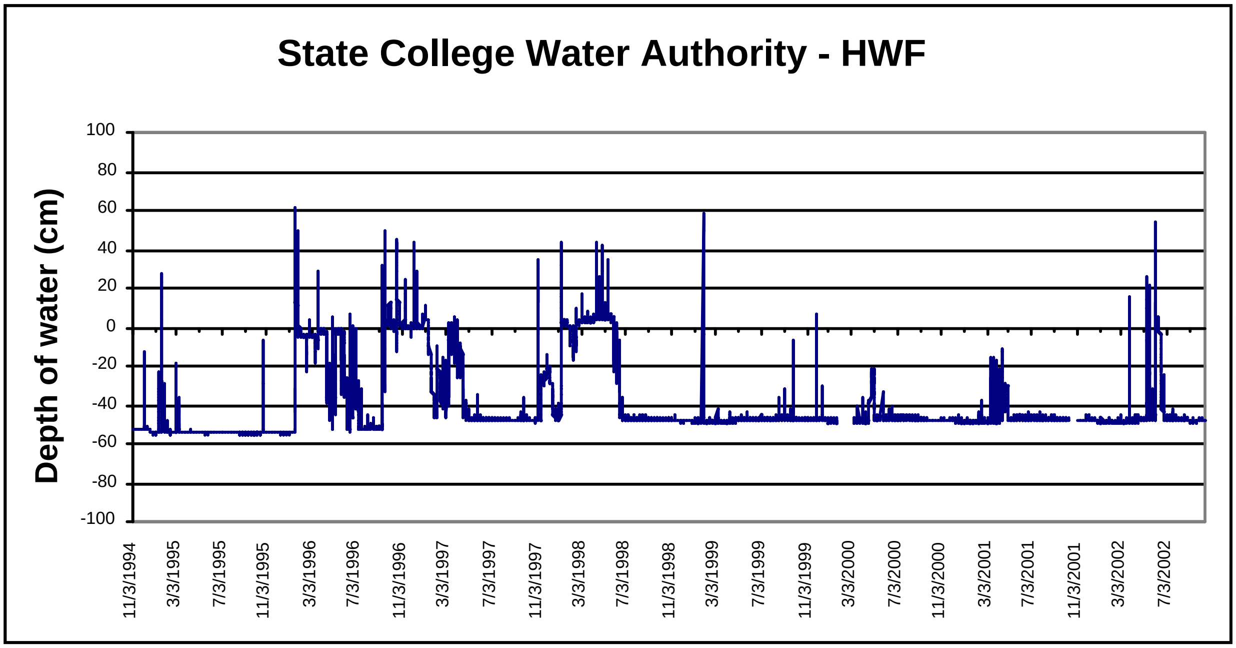
Hydrology & Floodplain and Channel Morphometry

While precipitation is the driving force in initiating a flooding event, the physical characteristics of the drainage basin, hydrology, and geomorphology of the stream-floodplain ecosystem are the primary factors controlling the concentration, spatial distribution, and dispersal rate of floodwaters (Staubitz and Sobashinski 1983, Scientific Assessment and Strategy Team 1994)(Figure 2). Small streams are more influenced by precipitation events and are more unpredictable than larger rivers (Junk and Welcomme 1990, Benke et al. 2000). Although climate and geology are important, they are generally considered to be similar within a given region and wetland type. Differences in landscape-level characteristics, such as upland indicators of disturbance and stream size are important characteristics to consider. Site-level indicators, however, can be utilized when necessary since they tend to be sufficient predictors for functional assessments (Brinson et al. 1995). According to the Riparian Area Management's Proper Functioning Condition Workgroup (1993), riparian-wetland areas are functioning properly when site-level indicators such as: adequate vegetation, landform, or large woody debris are present to dissipate stream energy and improve floodwater retention and groundwater recharge.

The physical characteristics of floodplain wetlands are important for assessing the potential of an area to store and manage floodwaters. Wetlands reduce the amount of runoff that reaches the streams by storing runoff from adjoining areas (Demissie and Khan 1993). This desynchronizes water delivery to streams, which decreases the frequency and magnitude of flooding downstream (McAllister et al. 2000). Unobstructed floodplains provide a broad area for floodwaters to spread across, which reduces water velocities, lowers flood peaks, and reduces erosion. Floodplain vegetation retards water flow and small topographic depressions temporarily trap floodwater (Owen and Wall 1989).

Human activities upstream influence flood frequency and intensity (McAllister et al. 2000). Urbanization creates impervious surfaces and underground sewers, which accelerate the delivery rate of surface water to the stream (Pennsylvania Environmental Council 1973). Channelization, levees, and floodwalls both on-site and upstream destroy wetland and riparian habitat, restrict river flows, decrease water elevations at low flows and increase water levels at the same locations during floods (Scientific Assessment and Strategy Team 1994). Channelization funnels water into the stream, rather than allowing water to spread across wetlands and decrease velocity (Brown 1988). This results in a decrease in the ability of wetlands to perform other functions, such as removing sediment and nutrients, and long-term surface water storage (Johnston et al. 1984, Brown 1988, Rheinhardt et al. 1999) and altering stream morphometry leading to scouring and incision. Highway embankments remove vegetation, eliminate natural storage areas, and reduce space available for floodwater storage (Owen and Wall 1989). These and other activities often result in channel degradation, which lessens the depth, frequency, duration, and predictability of flooding. The floodplain frequently becomes isolated from the stream channel and no longer has the opportunity to perform this function. In addition, these activities not only impair the performance on-site, but they also reduce the ability of downstream wetlands to dissipate energy and temporarily detain floodwaters.

Long-term surface water storage helps to maintain the characteristic hydroperiod of wetlands and streams. Hydroperiod affects just about all components of aquatic ecosystems; plant communities, soil processes, nutrient cycling and faunal communities are all influenced by the duration and frequency of inundation (Gosselink and Turner 1978, Carter 1986, Tiner 1998) and water dynamics (stream cites). Standard gauging stations have long been used to plot the expected hydrographs for streams and rivers throughout the U.S. These data are readily available digitally, although not all streams are gauged. On a smaller scale, the Penn State Cooperative Wetlands Center has prepared typical hydrographs (see below) of the expected hydrologic regime for making comparisons among wetland subclasses (Brooks 2004, Cole and Brooks 2000, Cole unpublished). Deviations from this expected pattern can be used to suggest the presence of watershed stressors.



Typical hydrograph for HGM Wetland Subclass - Headwater Floodplain.

The amount of flooding at a site is dependent on climate, topography, channel slope, soil and lithology (Novitski 1989, Brinson 1990). Physical characteristics of a site determine the ability of a wetland or floodplain to retain this excess water. The presence of macrotopographic depressions, whether hydric or not, affects the potential of a site to retain incoming waters for long periods of time. Features such as oxbows, meander scrolls, and backswamps all constitute macrotopographic depressions (Brinson et al. 1995). Various stressors may reduce the storage function of a wetland. Channelization increases the rate of runoff, which increases peak flow, and decreases water storage and the residence time of water (Brown 1988). Studies show that increases in water level fluctuation relate directly to increases in runoff from adjacent uplands (Euliss Jr. and Mushet 1996). Human alterations also cause an increase in the amount of sediment transported to a wetland. This may result in the filling of depressions, and hence a reduction in the storage capacity and topographic complexity of the wetland and the riparian corridor in general. The same source of sediment can fill critically important interstitial spaces in the substrate of streams.

Water Quality and Biogeochemistry

Measures of water chemistry in tributary watersheds are more reflective of the geologic and topographic characteristics of the landscape than for larger rivers. The complex geology of the Appalachians can create circumstances where relatively short stream reaches and individual wetlands can have a different water chemistry than their neighbors. Such variability influences biological communities, producing extraordinary biodiversity.

As pollution due to urbanization and agriculture increases, ponds, lakes and rivers begin experiencing a decrease in water quality. Wetlands and riparian corridors often act as buffers to these water sources due to their ability to filter out and transform contaminants.

Eutrophication from excess nutrients (e.g., nitrogen and phosphorus) can be a significant stressor in tributary watersheds. Nitrogen is one of the largest non-point source pollutants of stream systems. Often, nitrogen passes through riparian areas and wetlands before reaching the stream, so the ability of a these components to remove nitrogen is extremely important to stream water quality. Agriculture is the biggest non-point source polluter, causing elevated levels of sediment, nutrients, and pesticides Vought et al. 1994). While the application of fertilizer in general has increased since the 1960's, nitrogen fertilizers have by far been the element with the greatest increase (9 million metric tons) (Crumpton et al. 1993, Vought et al. 1994, Kadlec 2001). Studies show that as much as 50 - 90% of nitrogen fertilizer added to a cultivated crop is transported from the fields in runoff (Crumpton et al. 1993, Seitzinger 1994). Wetlands in the riparian corridor play an important role in improving water quality due to their capacity to permanently and temporarily remove nitrogen. Denitrification is the primary process of long-term nitrogen removal from wetland systems (Davidsson and Stahl 2000). In areas impacted by agriculture, denitrification may remove a significant amount of the nitrogen transported to wetland from fields, thus preventing its movement into streams (Groffman 1994). Research has shown a 90% or more reduction in NO_3^- concentrations in water as it flows through riparian areas (Gilliam 1994). Organic matter is also important in providing a substrate necessary for microbes to perform the process of denitrification. Plant uptake is an additional means of nitrogen removal from the system.

Anthropogenic impacts often lead to increases in nutrient inputs to wetlands and stream, thus altering their nutrient dynamics. Nitrogen fertilizer, one of the more common nutrient inputs in an agricultural setting, enters wetlands through groundwater and surface water runoff (Schlesinger 1997). Riparian forests retained 89% of total nitrogen inputs as compared to 8% for cropland, and the nitrogen loss from the forest was primarily via groundwater (Peterjohn and Correll 1984). Nitrate was an order of magnitude higher in streams draining agricultural watersheds compared to forested and wetland landscapes (Cronan et al. 1999). Thus, intact riparian corridors and wetlands can retain large amounts of nitrogen originating in upland agricultural areas.

Phosphorus loads also tend to increase with increasing disturbance, with the greatest loading associated with agriculture (Soranno et al. 1996). Riparian areas also can remove significant amounts of imported phosphorus. For example, in a floodplain wetland in Sweden, 95% of phosphorus entering the wetland in surface runoff was removed within 16 m Vought et al. 1994). In North Carolina, approximately 50% of the phosphorus leaving agricultural fields in runoff was removed in riparian areas (Cooper and Gilliam 1987).

The primary removal mechanisms for phosphorus and metals are the settling of particles out of the water column and adsorption to organic matter and clay. Long-term removal can be through roots, buried leaves, and sediment deposition (Richardson and Craft 1993). Finer soil particles carry more phosphorus than larger particles, and slower water movement will increase particulate phosphorus settling to the soil surface (Reddy et al. 1999, Mitsch and Gosselink 2000).

Sediment retention in wetlands and riparian corridors benefits neighboring streams, rivers, and lakes by reducing turbidity, and retaining phosphorus and contaminants that are sorbed to those sediments (Oschwald 1972, Boto and W. H. Patrick 1978, Cooper and Gilliam 1987, Hemond and Benoit 1988, Johnston 1991). The predominant delivery mechanism for sediment to tributary watersheds is the flow of water. Wetlands and floodplains are known to trap sediment in pristine settings, but accelerated sedimentation can quickly overwhelm the capacity of these habitats to store and process the sediments (Jurik et al. 1994, Wardrop and Brooks 1998, Freeland et al. 1999). High sedimentation rates decrease the germination of many wetland and riparian plant species by eliminating light penetration to seeds, lower plant productivity by creating stressful conditions, and slows decomposition rates by burying plant material (Jurik et al. 1994, Vargo et al. 1998, Wardrop and Brooks 1998). Excess turbidity caused by high levels of suspended sediment decreases oxygen levels and photosynthesis rates, impairs the respiration and feeding of aquatic organisms, destroys fish habitat, and kills benthic organisms (Johnston 1993b).

Landscape disturbances impact sediment loading and retention within the aquatic components of tributary watersheds. Hupp et al. (1993) found sedimentation rates to be highest in wetlands located downstream from agricultural and urban areas. Phillips (1989) found that between 14% and 58% of eroded upland sediment is stored in alluvial wetlands and other aquatic environments. As much as 90% of eroded agricultural soil was retained in a forested floodplain in North Carolina (Gilliam 1994). Eighty-eight percent of the sediment leaving agricultural fields over the last 20 years was retained in the watershed of a North Carolina swamp (Cooper et al. 1986). Approximately 80% of this was retained in riparian areas above the swamp and 22% was retained in the swamp itself.

Wetlands are a major source of particulate organic matter (POM) entering streams. Woody debris is a nutritional substrate, provides habitat for microbes, invertebrates, and vertebrates, is a substrate for seedling growth, and serves as a long-term nutrient reservoir; a consistent source of organic material (Harmon et al. 1986, Brown 1990). Particulate carbon is a small fraction of total organic carbon (TOC), but is of a disproportionately higher importance as a food source for fish and invertebrates (Taylor et al. 1990). POM is a nutritional source for stream fauna. Particulate organic carbon (POC) from wetlands contributes substantial amounts of carbon to stream channels (Dosskey and Bertsch 1994). In fact, POC comprises between 24% and 46% of the total organic carbon in streams (Dosskey and Bertsch 1994). Detrital inputs to the stream during peak inundation periods support microbial and macroinvertebrate communities in the stream channel (Smock 1990). The rate of particulate matter degradation depends on many factors, including soil moisture levels. According to Bilby et al. (1999), when compared to either fully submerged or terrestrial conditions, wood decays at a much faster rate when periodically wetted and dried, conditions typical of many wetlands and floodplains. Floodplains had higher decomposition rates for wood than streams (Cuffney 1988).

Landscape Patterns/Riparian Corridors
How humans interact with a landscape within the physical constraints of climate and geology defines land use. Land use can be considered a major driver of the characteristics and conditions of tributary watersheds. It is not only the type of land use that affects these watersheds, however, but also the patterns formed by the mosaic of land uses imposed over time. Of particular importance to aquatic ecosystems are the patterns that arise along riparian corridors (Jordan et al. 1993, Castelle et al. 1994). Both landscape patterns and riparian corridors are attributes that can be used to assess condition.

Comments on Stressors and Measures

When considering how various stressors influence tributary watersheds, it is instructive to consider deviations from reference sites of the highest biological integrity. In the eastern U.S., the best attainable conditions for tributary watersheds are derived from a landscape dominated by mature forests. Although a diversity of land cover types may be present (e.g., early successional forests, emergent wetlands, etc.), the dominant type is expected to be forest. Forested watersheds produce characteristic inputs of organic matter, shade over wetlands and narrow stream corridors, and habitat for an expected set of species. As humans transform the landscape, forest cover is generally reduced, replaced by agricultural, suburban, and urban land uses linked through transportation and utility corridors. The spatial extent and pattern of these changes determines the degree of alteration and degradation observed in tributary watersheds. Additionally, point sources of urban stormwater, agricultural runoff, and other pollutants can severely degrade tributary watersheds. Degrees of change can be detected through monitoring if selected attributes are used as vital signs.

In the Mid-Atlantic Region, and in particular the Appalachian Mountains, a number of initiatives have developed ecological indicators applicable to monitoring the condition of tributary watersheds. The Environmental Monitoring and Assessment Program (EMAP) of the U.S. Environmental Protection Agency developed and tested a variety of condition and stressor indicators for wadeable streams (Bryce et al. 1999, EPA 2000, Herlihy et al. 2000, Klemm et al. 2003). The Penn State Cooperative Wetlands Center (CWC) has produced a set of indicators for wetlands in the region based on rapid assessment techniques (Brooks et al. 2004) and the development of hydrogeomorphic (HGM) functional assessment models and indices of biological integrity (IBI) that were summarized by Brooks (2004). The CWC has developed and is applying a new set of monitoring tools to detect changes in condition and to diagnose the relevant stressors of these valuable aquatic ecosystems. A common thread through all of these techniques, is treating tributary watersheds holistically, rather than as a set of separate components. As a matter of efficiency, the first level of monitoring (Level 1) uses landscape analysis as a coarse filter to prioritize which watersheds are in most need of protective or restorative measures. With Level 1, the extent and pattern of land use can be identified as stressors. Once a watershed is selected for further study, rapid assessment methods (Level 2) are applied to refine the condition assessment and identify dominant stressors. More intensive methods (Level 3) are used to target specific sites to determine the extent of impact by stressors and to assess the integrity of biological communities (e.g., macroinvertebrates, amphibians, fish, plants).

Working toward a goal of integration, the CWC has developed and tested an expanded rapid assessment protocol that simultaneously samples the stream, wetland, and riparian components at sites that are compiled on a watershed basis (SWR, R. Brooks, unpublished). Specifically, the CWC's SWR Protocol uses as stressor checklist to simultaneously record the presence of stressors to in-stream, wetland, and riparian corridor portions. These stressors are shown in Figures 4 and 5. When more detailed measures of condition are needed to assess either the degree of degradation or the success of restoration, the CWC has developed HGM functional assessment models for relevant wetland subclasses in the region. IBIs have been developed for both wetland and stream macroinvertebrates, wetland and stream amphibian communities, and wetland vegetation (Brooks 2004). Fish IBIs, when appropriate for larger streams and rivers, are available (Barbour et al. 1997, EPA 2000).

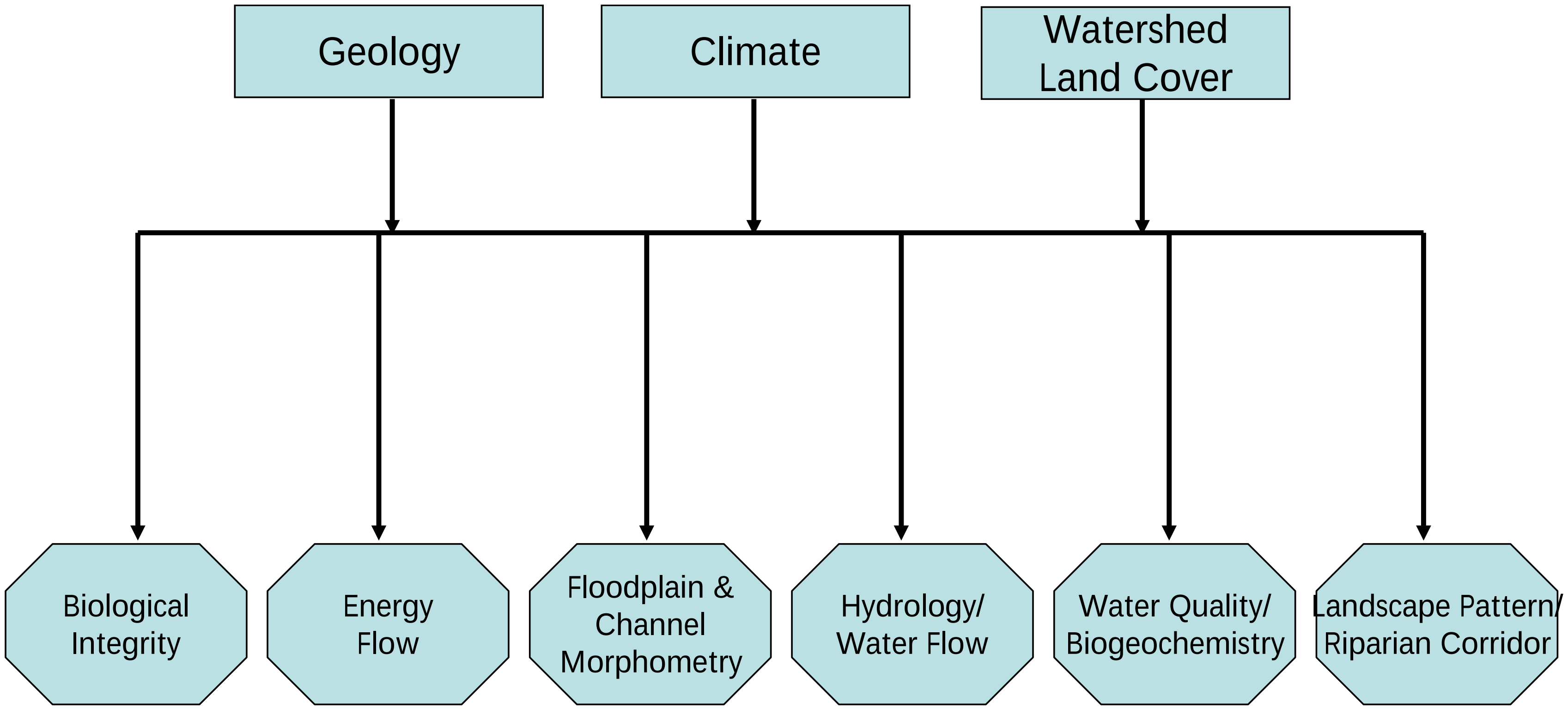


Figure 1. Tributary Watershed Natural Drivers (rectangles) and Attributes (octogons).

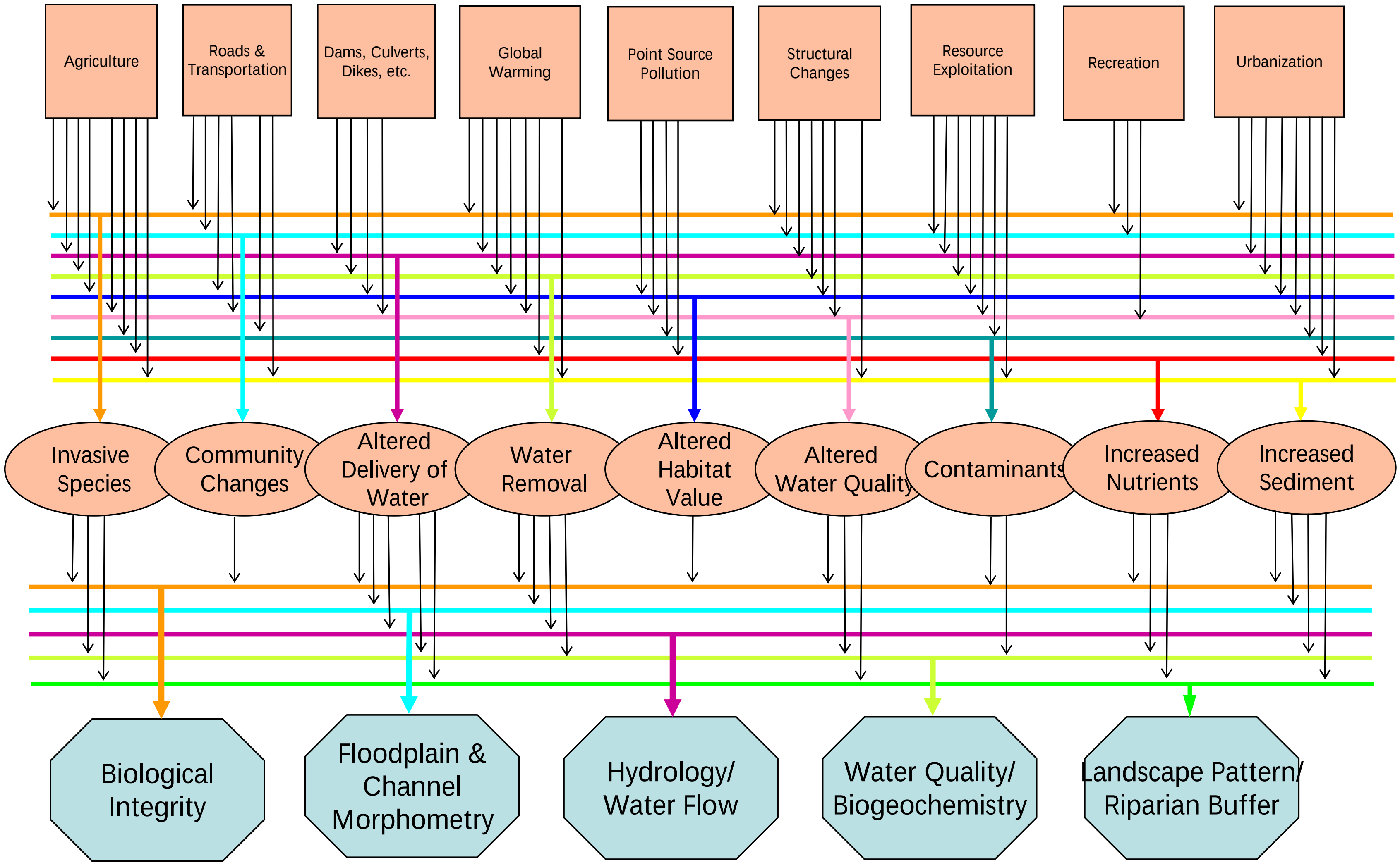


Figure 2. Tributary watershed anthropogenic drivers (rectangles), stressors (ovals), and coarse-level vital signs (octagons). Each vital sign and stressor is represented by a thick, colored line. Connections (probable causal linkages) between drivers and stressors, and between stressors and vital signs, are represented by thin vertical arrows.

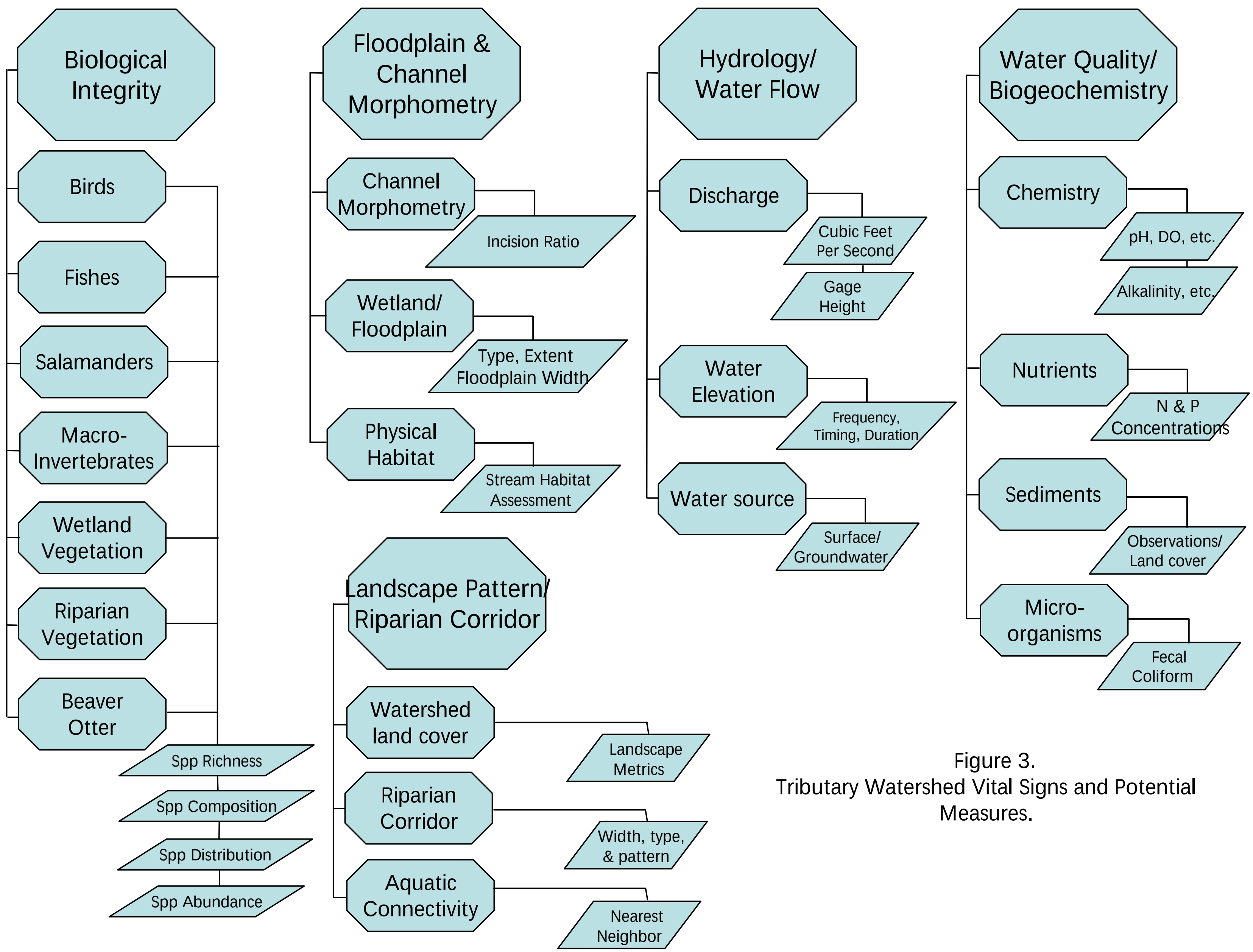


Figure 3.
Tributary Watershed Vital Signs and Potential Measures.

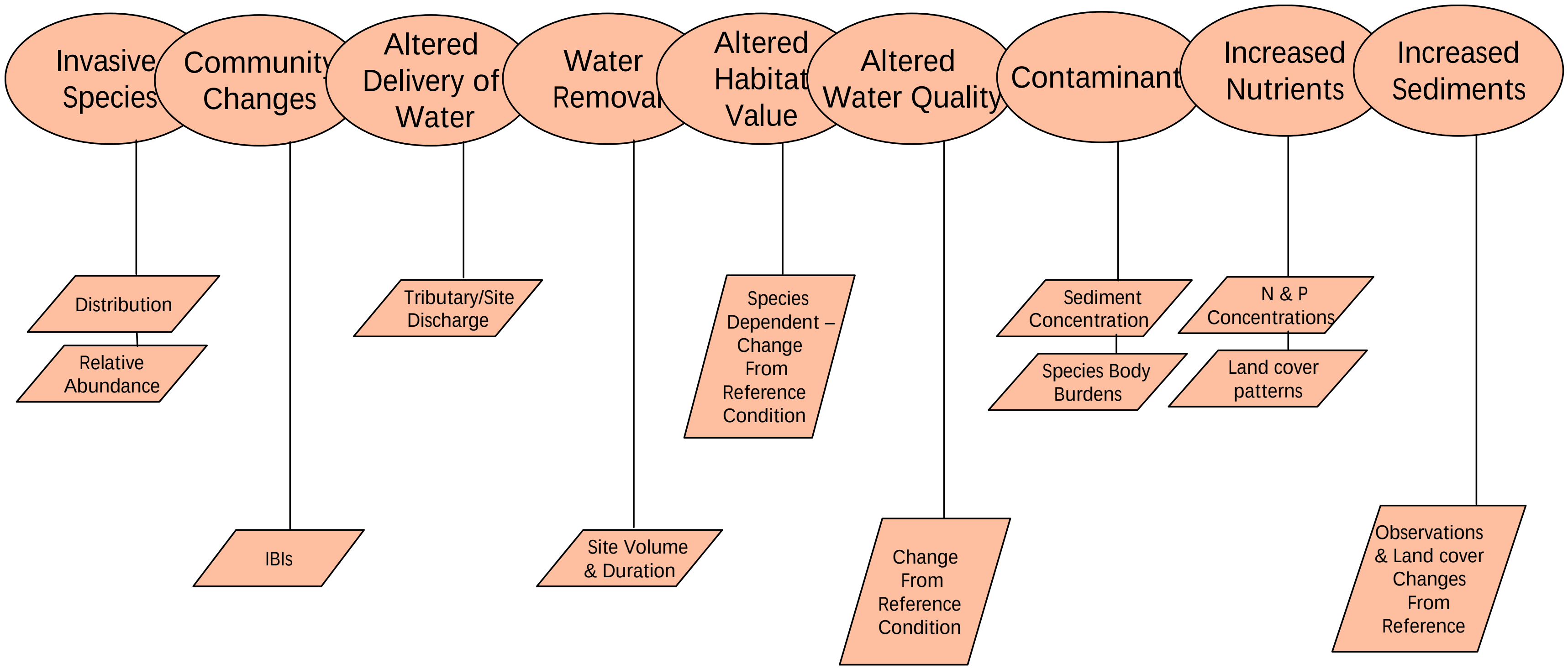


Figure 4. Tributary Watershed Stressor Measures.

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2.4 Terrestrial Ecosystems Model

Model Leads

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Introduction

This section is intended to be the preliminary, general, terrestrial ecosystem conceptual model for all Park Units that fall within the Eastern Rivers and Mountains Network. The information presented here will be a starting point for future discussions and workshops that focus on particular elements of the model and the needs for, and implementation constraints to, monitoring in the Eastern Rivers and Mountains Network.

The purpose of conceptual models in development by the Eastern Rivers and Mountains Network, is to "promote communication and integration among scientists and managers from different disciplines during the vital signs selection process". As such, this model and associated narrative is not only an attempt to present a brief scientific description of terrestrial ecosystems and their essential ecosystem characteristics and attributes, but also, and perhaps more importantly, to identify and describe the most serious anthropogenic threats to these systems and describe how these threats alter the integrity of various ecosystem attributes.

The model provides a list of potential measures that could be adopted in a long-term ecological monitoring context to track the status and trends of essential ecosystem components and associated threats.

Terrestrial Ecosystem Conceptual Model

The description is accomplished by using a diagrammatic conceptual modeling approach that focuses on six primary ecosystem attributes that are affected by three natural drivers (Figure 1). Geology, climate, and disturbance have often been considered as primary drivers of terrestrial ecosystems. The ERMN lies within temperate latitudes, which provides a relatively mild climate with favorable growing conditions. Rainfall and temperature patterns vary across the network partly due in part to differences in latitude, prevailing weather systems, and differences in topography at several spatial scales. These large and small scale differences help explain (i.e. "drive") the varied terrestrial communities present in the ERMN. The maintenance of many of these habitats is dependent upon natural disturbances such as fire, wind, flooding, landslides, ice storms, insect cycles, and occasionally hurricanes. Ecologically, these natural disturbances have played a large role in determining many of the intricate landscape patterns that characterize the ERMN both spatially and temporally. Under undisturbed conditions, each of the six ecosystem attributes varies over time, responding to seasonal, annual and long-term changes in the three drivers.

As with most ecosystems of the world, the terrestrial systems of the ERMN are and have been greatly influenced by (and in some cases maintained entirely by) humans. Figure 2 displays the anthropogenic drivers and stressors discussed most often in the literature, as well as their perceived connections to the attributes. These anthropogenic drivers, and stressors and comments on how they affect terrestrial systems are discussed below.

Figures 3 and 4, respectively, illustrate measures of fine-level attributes and stressors that are applicable to terrestrial ecosystems. These measures are *proposed* to begin discussions of what are the appropriate and logistically possible elements for monitoring within the Park Units. As with the earlier discussion of the relative importance of different drivers and stressors, continued dialog about vital sign and stressor measures requires more detailed knowledge of spatial heterogeneity within the Park Units. That knowledge is necessary to begin developing an efficient and effective monitoring design that would yield scientifically valid data, and information that is relevant to management decisions.

Comments on Anthropogenic Drivers and Stressors

Habitat Loss and Fragmentation

Habitat fragmentation is a process by which contiguous habitats are reduced in size and the remaining habitats are divided into patches. The patches that remain are often isolated from each other within a modified or degraded landscape. Habitat fragmentation can be caused by a wide range of temporal and permanent anthropogenic causes (Meffe et al. 1997). Temporal causes of habitat fragmentation can include forestry practices such as clearcutting or fire management and more permanent fragmentation changes can include loss of land due to agricultural conversion, urban sprawl, and the development of roads. Although temporary fragmentation can be necessary and beneficial for some habitats and species (i.e., that which mimics natural disturbances) and is often managed for, permanent fragmentation is the most severe form of habitat loss and resultant threat to biodiversity. Fragmentation can cause disruptions to biodiversity on many levels, including loss of genetic diversity, loss of species due to habitat removal, loss of remaining suitable habitat, isolation effects, susceptibility to disease, barriers to dispersal, altered disturbance regimes and others (e.g. Dessecker and Richard 1987; Ehrlich 1988; Hoover et al. 1995; Yahner and Ross 1995; Mahan and Yahner 1996; Mahan and Yahner 1999, Thornton et al. 2000; Fleming and Giuliano 2001; Williams 2001).

Pollutants, Toxins and Contaminants

There is a long list of pollutants and toxins associated with air or water quality that can directly poison organisms or otherwise impair terrestrial (and aquatic) ecosystems. The US EPA (http://www.epa.gov) web site contains a listing of all of the known sources of contaminants as well as information about point source and non-point source regulations, studies, etc.

Non-point source Pollution.- This type of pollution typically originates from a wide variety and dispersed suite of sources and typically enters waterways and terrestrial systems from either snowmelt or rainwater moving over ground, disrupting the immediate area as well as those areas downstream. There are many sources for this type of pollution, including nutrients such as phosphorus and nitrogen from agricultural lands, runoff of sediments and chemicals from construction and development projects, herbicides and pesticides from lawns, drilling for oil and gas and acid precipitation (EPA 1993). Agriculture and abandoned mines currently are the two largest contributors to non-point source pollution in the region (Arway 1999; PADEP 2001).

Point-source pollution.-As the name implies, these sources are usually from a discrete source and includes sewage treatment plants and industrial plants where the pollution is typically discharged directly into a waterway or across a terrestrial system. Programs to control the amount of point source pollution have been more successful than non-point sources pollution programs in reducing pollutants entering waterways (US EPA and Chesapeake Bay Foundation).

During the last decade, an significant number of amphibian limb abnormalities have been reported across the country. Although the Northern Leopard Frog (*Rana pipiens*) is the most commonly reported species with deformities, many other species have been reported as well. The causes are still not completely known, although possible sources include an increase in UV-B radiation, increase use of pesticides and other toxins, and an increase in tremetode infections brought on by other causes. There is some evidence that these causes act in concert to weaken amphibian immune systems thus making them more susceptible to tremetode infections. The North American Reporting Center for Amphibian Deformities has information, references and reporting sheets for this threat to amphibians (http://www.npsc.nbs.gov/narcam/).

There is also evidence to suggest that various contaminants may have contributed to the decline of some raptor species such as the Cooper's hawk (see review in Pattee et al. 1985). More recently, an examination of contaminants of the possibly declining Sharp-shinned hawk revealed that DDE, PCB's and mercury were detected in high, but sub-lethal levels on the Kittatinny Ridge in eastern Pennsylvania (Wood et al. 1996). It is still unknown if the sub-lethal concentrations of these and other compounds can cause impairment or reproductive losses.

Urbanization

Because expanding populations will require additional space for homes, schools, businesses, etc., some growth is inevitable. However, unmanaged growth characterizes urban sprawl and presents increased negative costs to both humans and biodiversity. The following real estate development can be characterized as urban sprawl:

- low density
- unlimited and non-contiguous outward expansion
- spatial segregation of different land uses
- consumption of outer suburban agricultural lands and environmentally sensitive lands
- travel dominance by motor vehicle
- small developers operating independently of each other
- lack of integrated land use planning

The five counties surrounding DEWA have experienced some of the most rapid residential development in the United States during the past several decades (250 percent growth during the period 1970 to 1990). Pike County (PA) has been the fastest growing county in Pennsylvania since 1970. Recent estimates indicate local populations have grown by more than 50 percent since 1990. Furthermore, these census figures do not include the continuing proliferation of vacation homes in the area, because they are not "primary residences." The human population in many area developments is three to six times greater during summer weekends and holidays than during the winter. For example, the year-round resident population of one such development (Hemlock Farms) is about 2,500, but on summer weekends this population swells to over 10,000 (from USGS study plan).

This increasing need for more space has prompted a loss of prime farmland and open space and forested areas, thereby decreasing the amount of land available to all species. However, there are also less obvious effects, including problems with stormwater runoff due such sources as construction, increased asphalt, and pesticide use, which can adversely affect the quality and quantity of water sources in the area. At least two studies have cited evidence that despite efforts to restore or retain riparian buffer zones or create detention ponds in urban or suburban areas, the increasing amounts of impervious surfaces in these areas will overwhelm the ability of riparian buffers to control non-point sources of pollution (Booth and Jackson 1997; Hession, Johnson et al. 2000; Boesch, Brinsfield et al. in press).

Agriculture

The region is greatly influenced by agriculture. For example, approximately one quarter of Pennsylvania's land is in farmland or cropland and is the state's primary industry; with dairying as the leading agricultural industry (PA Farm Bureau (http://www.pfb.com/)). Agriculture has also been the source of many problems, primarily in the form of non-point source pollution from manures, fertilizers, herbicides and pesticides (Arway 1999). Livestock that are allowed to enter riparian areas disrupt streambanks, increasing erosion and sedimentation into the stream system (Novak and Woodwell 1999). Loss of the riparian zone either due to removal for crops or livestock also degrades stream systems by removing vegetation, destabilizing banks, and increasing water temperatures (Wohl and Carline 1996; Palone and Todd 1997). The loss of riparian stabilization also allows fertilizers, pesticides and herbicides to more easily enter streams, causing both eutrophication of water and toxicity to aquatic life (Boesch, Brinsfield et al. 2001).

Acid Deposition

Acid deposition, which results from release of sulfur and nitrogen dioxides during the burning of fossil fuels, automobile exhaust and other industry, can occur as either wet (rain or snow) or dry deposition (Wilderman 1989). As these pollutants mix with water vapor, sulfur and nitric acids are formed which negatively affect both terrestrial and aquatic ecosystems.

Chronic acidification generally refers to streams, lakes, and soil ecosystems that have lost their ability to neutralize acidifying events. Base nutrients such as calcium, potassium, and magnesium, and other types of neutralizing chemicals buffer changes in ecosystem acidity. However, when ecosystems are exposed to excessive, long-term acid deposition these chemicals become depleted. This can make the system more vulnerable to episodic acidification events and may lead to chronic surface water acidity (Ecological Society of America definition).

There are many good overview publications on the effects of acid precipitation on aquatic ecosystems (Lynch and Corbett 1980; Sharpe 1990; Bradt 1994). There have also been many individual studies on the effects of acid precipitation on forests, water quality, fish and macroinvertebrate populations, and many of these have been done in the Laurel Hill area of eastern Pennsylvania, where acidic conditions have been comparatively high during the last two decades (e.g. DeWalle, Sharpe et al. 1982; DeWalle, Dinicola et al. 1987; Sharpe, Leibfried et al. 1987; Sharpe, Perlic et al. 1987; Kimmel, Cooper et al. 1996; Sharpe and Demchik 1998). There is also a comparatively large amount of information on the effects of acidity on amphibian populations as compared to other potential threats (e.g. Freda and Dunson 1985; Freda and Dunson 1986; Dunson, Wyman et al. 1992).

While there may be some indications that acidic conditions are improving due to reduced sulfur emissions (Driscoll et al. 1998; Stoddard et al. 1999), it is unknown as to the length of time needed for forested systems to recover (Drohan and Sharpe 1997).

Acidic precipitation can cause both short and long term changes in soil nutrients, thereby changing the availability of these necessary nutrients to trees. Damage to the root tips of trees by increased aluminum concentrations may result in reduced ability for the tree to take up calcium and magnesium (Schneck et al. 1999). Calcium and magnesium may also leach into the water due to an increase in positive ions from acid precipitation and is ultimately carried downstream, thereby unavailable to plants or trees. There is evidence that the decline of both sugar maples and northern red oaks may be linked to these processes (Schneck et al. 2001)

In the Laurel Hill region (Sharpe and Demchik 1998) note that the mortality of red oaks have become a problem in parts of the region and may be due to increases in soil acidification. Fish losses occurred at least 30 years ago and may be good indicators of future forest health due to acidification. (Drohan and Sharpe 1997) have observed changes in soil chemistry due likely to changes brought on my acidity. However, (Nash et al. 1992) found no relationship between health of several tree species and a gradient of forest soil pH.

There have been a large number of studies on how acid precipitation affects the reproduction and viability of salamanders in the region (Rowe et al. 1992; Horne and Dunson 1994; Horne and Dunson 1994; Horne and Dunson 1995). The Jefferson Salamander (*Ambystoma jeffersonianum*) has been shown to be sensitive to conditions of low pH (and associated aluminum concentrations) and may be the major factor responsible for the successful breeding of this species in the state (Horne and Dunson 1994; Horne and Dunson 1995).

There is less information on how different frog and toad species respond to acid precipitation , although the Wood frog (*Rana sylvatica*) has been shown to be more tolerant of low pH conditions. In contrast, the Fowler's toad (*Bufo woodhouseii fowleri*) shows significantly slower growth at low pH (Freda and Dunson 1986) and is absent from the most acidic ponds.

Ozone
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Roads and Transportation
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Invasive Species
The threats posed by introduced or invasive species to native biodiversity has been both a controversial and difficult issue, leaving many questions as how to best deal with the problem. As the world becomes increasingly accessible, aquatic and terrestrial species from other parts of the world will continue to be transported (Mack et al. 2000). The threats that introduced species can pose to other native species can fall along a spectrum of benign to severe, although it is usually difficult to determine exactly how any exotic species will behave when it is first accidentally or intentionally introduced (Slobodkin 2001). For those species that are considered invasive or pest exotics, the threats can come from the displacement of an native species with an exotic by competition or predation, the hybridization of a exotic and native species, or the introduction of a pathogen that an introduced species may be carrying (e.g. Mack et al. 2000; Kiesecker et al. 2001). Although many introduced species have caused little problem to native wildlife, others such as the hemlock wooly adelgid, zebra mussel, and numerous plant species have been documented to cause extensive damage to an ecosystem. The vast majority of introduced species have only anecdotal accounts of their occurrence and spread, making an assessment of their effects difficult. There is also little information on how these species affect other native organisms and the ecosystem as whole.

Climate Change
A predicted change in climate has the potential to affect the region's land and water resources, although many aspects of these changes are, not surprisingly given the scale of the problem, uncertain (Sala et al. 2000; Currie 2001; Hansen et al. 2001).

The U. S. Global Change Research Program released a comprehensive summary report in 2000 on the potential impacts of climate change in the United States. A summary of the results that were found for the mid-Atlantic states can be found at: (http://www.climatehotmap.org/impacts/midatlantic.html)

A report from the Mid-Atlantic Integrated Assessment (EPA 2001) details how the region will be affected by climate change. This report focuses on how increased climate variability and change would affect forestry, agriculture, fresh water, coastal zones, human health and ecosystems. Preliminary findings relevant to this narrative suggest that:
- Climate change will compound existing problems from existing stressors.
- Sea-level is rising 1-2 inches per decade along the Mid-Atlantic coastlines.
- Floods and droughts could be more frequent and severe.

• Trout and other cold-water fishes may become less abundant due to warmer temperatures.
• Invasive species that thrive in warmer and wetter climates could displace native species.
• Maple, beech and birch forests may be replaced by oak, hickory and pine forests.
• Some of the uncertain impacts include warmer temperatures, greater average streamflow and a greater warmwater fisheries. However, there may be more variability in freshwater quantity and an increase in runoff.

A summary of the report can be found at:
(http://www.epa.gov/emfjulte/tpmcmaia/html/reports.html)

Deer
The White-tailed deer (*Odocoileus virginianus*) and its effects on terrestrial ecosystems is an interesting, controversial, and important topic. Deer populations have fluctuated widely in the region over the last century. For example, deer were nearly extirpated in Pennsylvania in the last century due to overhunting (PA Game Commission) however, the widespread removal of forest during that time period in concordance with strict hunting regulations and the loss of larger predators in the 19th century, caused an increase in their populations, resulting in an estimated population size of nearly 1 million by the 1930s (Forbes et al. 1971, Rooney and Dress 1997, Yahner 1997). Their population has continued to expand into this century and their population is now estimated at approximately 1.5 million (PA Game Commission), well over the PA Game Commission's target population size. The same generalization can be made in other parts of the ERMN, however it should be noted that there is spatial variation in the distribution and population density of deer. In general, the increasing numbers of deer as well as their wide range of preference for a variety of native plants and shrubs has caused a number of problems for both forest biodiversity, forest regeneration, as well as human health (car accidents).

Many correlative studies on declines in either certain plant or small tree species and density of deer exist (e.g., Bowles and Campbell 1993). For native plants, several studies have found that deer have a negative effect on understory plants (Ruhren and Handel 2000; Rooney 2001), including the endangered Glade spurge (Loeffler and Wegner 2000). Although (Campbell 1993) found that deer caused decreased reproduction and mortality of some of the endangered perennial *Lithospermum caroliniense*, other factors were more likely the cause of decline. There also seems to be a correlation with the density of hay-scented fern, which deer do not eat, and the loss of herbaceous species (Rooney and Dress 1997). In some areas, where fencing has been put into place or deer densities have been reduced, plants may return, although some may never recover.

There is also evidence that deer may prevent the regeneration of some forest plants and trees (Decalesta 1994; Rooney 1995; Fredericksen et al. 1998) and are therefore changing the structure of the region's forests. Even though many studies suffer from poor study design and/or have not controlled the effects other factors that may explain the decline in tree densities or species, the evidence suggests that deer have influenced the growth of certain species (positively and negatively) which, in turn, affects forest structure and regeneration.

As the amount and type of understory appears to decrease with increasing deer density, there are also indications that the amount of habitat suitable for birds nesting in the mid to lower canopy also declines. Yet, Decalesta (1994) found no effects on the abundance of ground or canopy nesting species, however, species richness and abundance was lower for some species. Casey and Dale (1983) found that avian species composition was different in and outside of reserve and was attributed to differences in tree species composition (and therefore deer browsing).

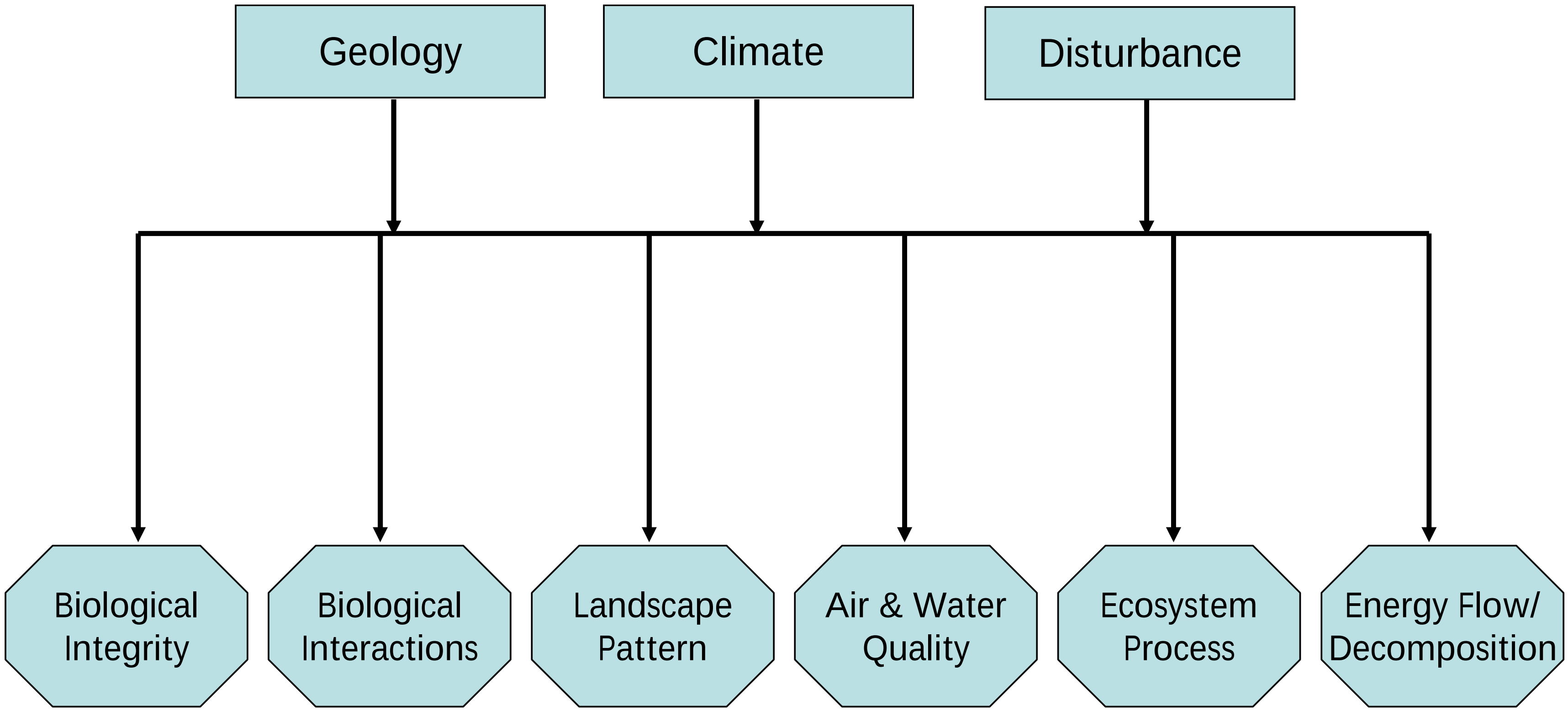

Figure 1. Terrestrial Ecosystem Natural Drivers (rectangles) and Attributes (octagons).

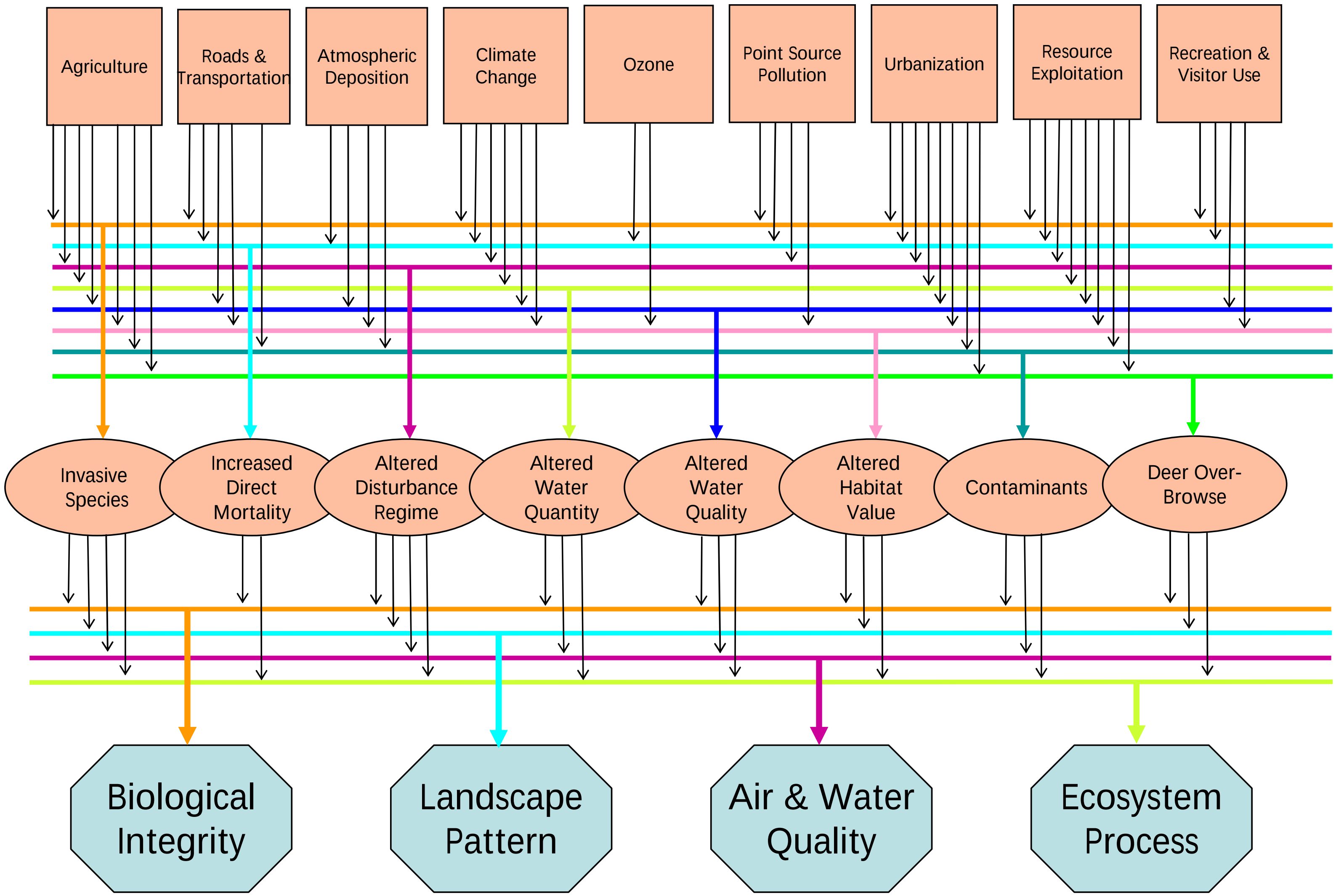

Figure 2. Terrestrial System anthropogenic drivers (rectangles), stressors (ovals), and coarse-level vital signs (octagons). Each vital sign and stressor is represented by a thick, colored line. Connections (probable causal linkages) between drivers and stressors, and between stressors and vital signs, are represented by thin vertical arrows.

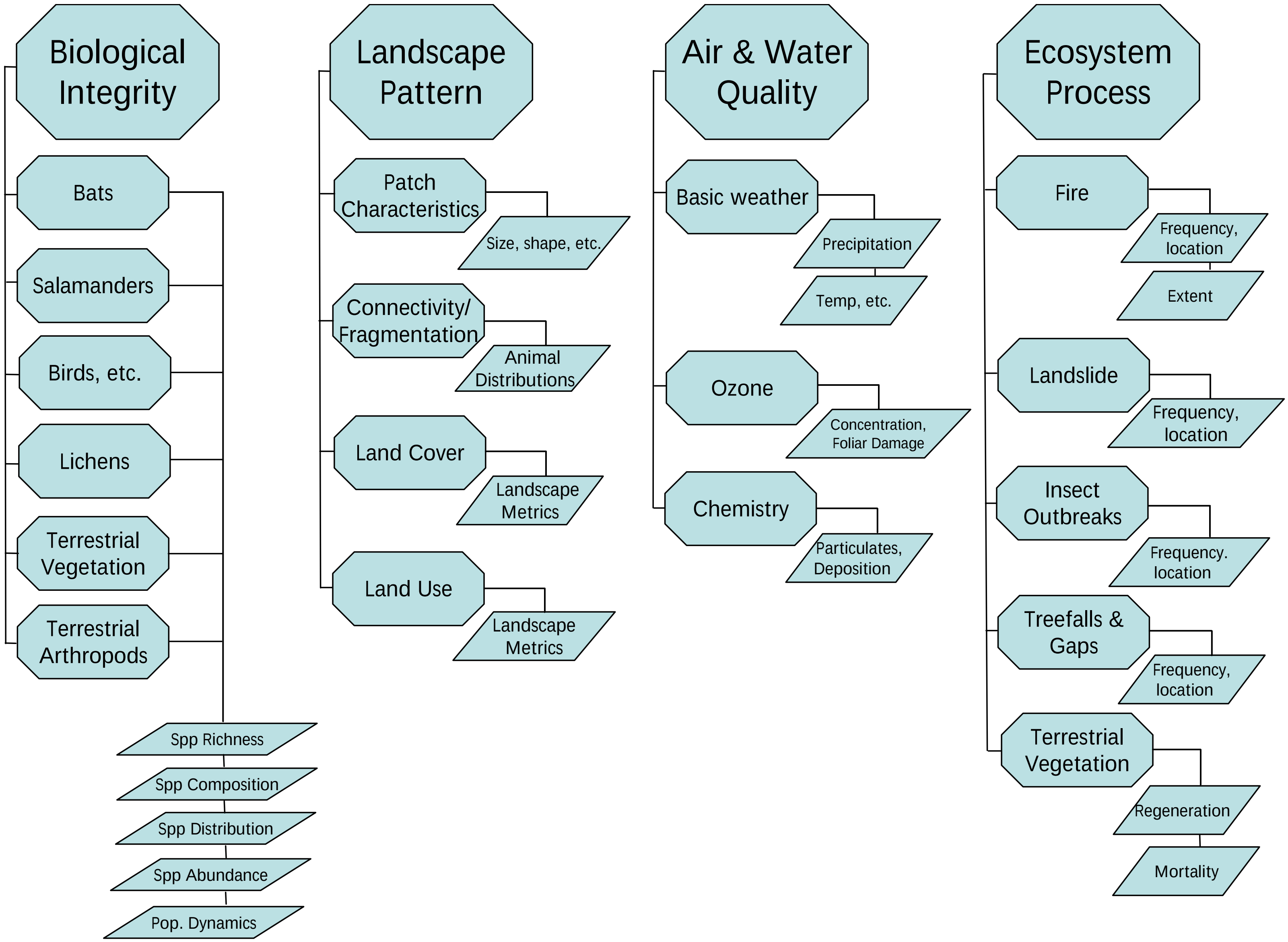

Figure 3. Terrestrial Ecosystems Vital Signs and Potential Measures.

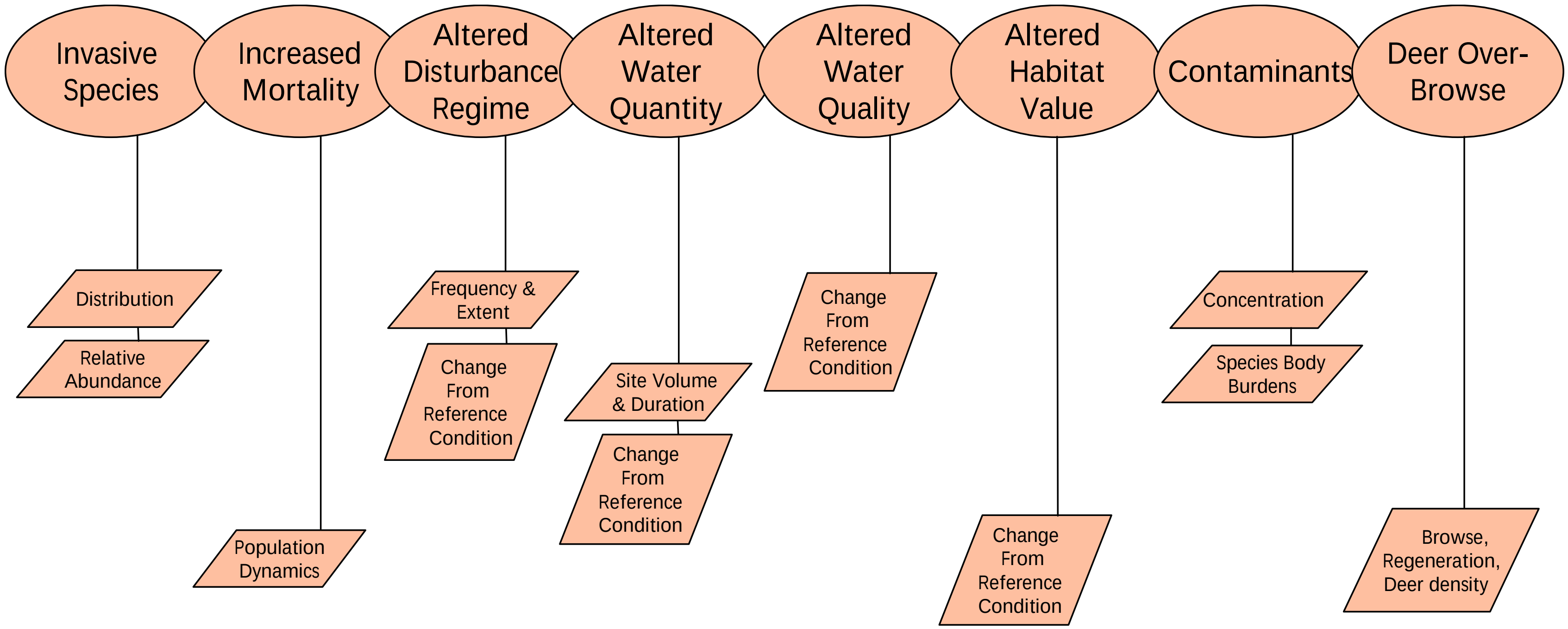

Figure 4. Stressor Measures.

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Chapter 6. Data Management

6.1 Introduction

6.1.1 Data Management Overview and Scope

Data and information are the core units of the research or monitoring process. Without the recording of measured values and observations, there is no data to analyze, or information to interpret. In the field of ecology, datasets often represent valuable information from observations or field experiments that cannot be repeated. In long-term ecological projects, datasets are often revisited years or even decades after they've been created and can enable, or disable, contemporary scientists to arrive at conclusions or come to new understandings (Michener and Brundt 2000). As such, data lies at the absolute core of the National Park Service's Inventory and Monitoring (I&M) Program, and without its responsible management, the program will never meet its objectives or fulfill its goals.

Management of ecological datasets has been problematic for as long as there has been an active discipline of ecology. This has resulted from a number of circumstances. First, data management principles have their roots in the business sector and anyone who's taken a recent data management class or training will note that many of the examples still come from the business sector. Ecological datasets most often have unique complexity that lessons learned from business fail to address. Though the discipline of data management has been slow to embrace science and ecology, there exist several excellent books on the topic (see Michener and Brundt 2000).

Although shortcomings in data management techniques and principles certainly do not help ecologists manage their data, perhaps the most difficult issues to overcome have, and continue to be more social in nature. Ecologists are most often charged with managing their own datasets; however, most ecologists have chosen their professional path to practice the discipline of ecology, not to manage data! The unfortunate result has become a history of poorly managed ecological datasets, not so much for a lack of scientific or technological sophistication, but because of poor data management practices.

Because of the aforementioned state of affairs, the I&M Program has had the foresight to hire a Data Manager into every Network across the country. The Network Data Manager is to work with the Network Coordinator and scientists to assure the responsible management of network, and in some cases park, datasets. That said, with the volumes of data being generated by networks the data manager cannot, and should not, attempt to manage all network data by her or himself. In this role the Data Manager is more of a champion of data management, providing expertise, encouragement and assistance where needed. Finally, it is imperative that the Data Manager work closely with, and have the full support of the Network Coordinator as they both depend on one another to fulfill their professional responsibilities and performance goals.

6.1.2 Data Management Goals, Objectives and Philosophy

The National Park Service's Inventory and Monitoring Program has been charged with providing scientifically sound, accurate and permanent data on park natural resources to inform the resource management and decision-making process. Although well tested and developed field survey protocols, statistical analysis techniques and expert interpretation are all important components of creating the aforementioned data sets, so is good data management. Good data management should:

- Be people oriented, offering practical solutions that can be adopted with relative ease
- Involve scientists, seeking out their input and advice
- Be based on good habits of organization
- Be simple, easy to follow and flexible
- Not rely on technological sophistication or computing complexity
- Be a reflection of individual field protocols with a unique set of practices for each
- Ensure data quality, integrity, accuracy and permanency
- Provide end users with all information necessary to easily access, explore, and manipulate data for the foreseeable future

6.2 Data Management Roles and Responsibilities

6.2.1 Data Management Roles

6.2.2 Data Management Coordination

6.2.3 Shared Responsibilities

6.3 Data Management Infrastructure

6.3.1 Hardware

Over the course of the last year the ERMN has acquired numerous hardware items to facilitate network operations; these include:

Table 1. List of Hardware Resources

Item	Description
Computers	1 Dell Optiplex GX 270 Intel Pentium 4, 3.00GHz; 2.0GB RAM; 160GB HD; CDR, DVD+RW 2 Dell Optiplex GX 270 Intel Pentium 4, 3.00GHz; 2.0GB RAM; 160GB HD; CDR, DVD/CDRW 1 Dell Optiplex GX 270 Intel Pentium 4, 3.00GHz; 1.0GB RAM; 160GB HD; CDRW 1 Dell Inspiron 8600 Intel (M) 1.80GHz; 640MB RAM; 60GB HD; DVD/CDRW [Notebook]
Printers and Scanners	1 HP 4600dN color laserjet printer with duplexing 1 HP scanjet 5550c scanner
Pocket PCs	1 Compaq IPAQ 3760 Pocket PC
Portable storage devices	2 Maxtor External 160GB HD 2 256MB mini datasticks

6.3.2 Software

Over the course of the last year the ERMN has acquired several pieces of software above and beyond the standard Microsoft Office Professional suite of software to facilitate network operations; these include:

Table 2. List of Software Resources

Software Category	Description
GIS	ESRI ArcGIS 9.0; ESRI ArcGIS 8.3 and ArcGIS Workstation 8.3; ESRI Arcview 3.3
Digital Imaging	Adobe Acrobat 6.0 Professional and Distiller 6.0, ImageReady CS and Photoshop CS
Web Development	Macromedia Dreamweaver and Fireworks MX
Reference Management	EndNote 5.0
Statistical Analysis	SAS for Windows 8.0

6.4 Data Management Highlights to Date

6.4.1 NPSpecies and NatureBib

Two Pennsylvania State University Research Associate Cooperators (in Jennifer Stingelin Keefer and Scott Tiffany), have been working on the ERMN NPSpecies and NatureBib databases for four and seven years respectively. Their work has been invaluable and they are in the processes of building accurate, up to date and useful databases for the network. They represent the bulk of expertise in these two databases for the network and they are truly a highlight in the ERMN's data management progression.

6.4.2 Webpage and Digital Imaging Development

In the spring of 2004 the ERMN Data Manager took over responsibility for building and populating the network's internet webpage. The webpage has become the principal mechanism to disseminate news happenings in the ERMN, reports, data, and general overview and contact information. Also in the spring of 2004, as a result of exposure to the NPS Synthesis program and a meeting with its developer, the ERMN became convinced of the utility of creating and distributing digital documents relevant to network activities via the ERMN webpage. This is still a project in progress, however a vision of a web accessible, searchable database of downloadable literature resources with interoperability with the NatureBib database is taking shape.

6.4.3 Digital Transfer of Historic Data

In the spring of 2004, the ERMN contracted Geta Dragut (a GIS intern at Delaware Water Gap), to transpose field tabular and spatial data from a historical 1994 aquatic plants survey to various digital formats to be used for comparison with a more recent aquatic plants survey. What Geta created turned out to be more than a simple data product; she developed a technique for retrieving non-digital data from historical projects and converting them to digital formats in an efficient and effective manner. Her proposed process included quality assurance and verification error checking routines to ensure data integrity. Geta presented this project at the ESRI User's Conference in San Diego, California August 9-13, 2004.

6.4.4 Park Data Recovery

One function of the I&M program is to serve as a repository of data and institutional knowledge for each network. As NPS staff move around they often take specific and sometimes irreplaceable knowledge with them. Sometimes this knowledge is as simple as where a certain report may reside in a computer's folder structure, a shelf in an office, or a storage facility. In an attempt to address this problem and serve as the a centralized data repository, ERMN staff have begun a program of paying visits to park staff before their departures to transfer data files and more personal knowledge of datasets and resources. In June of 2004 Laura Pickens, GIS Specialist for NERI moved on to another position elsewhere. Before her departure Network staff paid her a visit to both transfer digital data files and meet with other park staff to establish new points of contact. Not only is a personal appearance needed due to the shear volume of data being transferred, but also the ERMN believes that this kind of personal interaction is necessary in order to establish and maintain report with park staff.

6.4.5 GIS Intern

The ERMN is in a unique situation in that they're duty stationed at the Pennsylvania State University. The University setting affords many opportunities including easy access to academic expertise, as well as access to a plethora of semi-skilled part time help. In the name of maintaining positive relations with the public and University, and cultivating interest in the student body in the National Park Service, the ERMN took on a GIS intern in the summer of 2004. John Dooris is a Senior in the Geographical Information Science option of Geography at the University and is interested in GIS applications ranging from natural resource management to regional planning. John was charged with various spatial data mining, acquisition, management and manipulation tasks including assembling a core set of base cartography for ERMN parks. In return, John learned much about the ESRI ArcGIS environment, the power of ArcGIS Workstation and at the beginning of the new semester felt ahead in his upperclassman GIS course.

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ACKNOWLEDGMENTS

The development of a successful long-term ecological monitoring program will not be possible without the support of many dedicated individuals. We wish to thank Gary Williams, Steve Fancy, John Gross, and others with the National Inventory & Monitoring (I&M) program for guidance and support. We also wish to generously thank Beth Johnson, Northeast Region I&M Coordinator, for all that she has done for us and the program. The Resource Managers and their staffs at each of the parks deserve special thanks for your invaluable knowledge, help, and guidance—this program would not be possible without you, and, ultimately, is for you and the resources under your care.

The Inventory and Monitoring Program was made possible through the National Park Service Natural Resource Challenge.

GLOSSARY

Adaptive management - systematic process for continually improving management policies and practices by learning from the outcomes of operational programs. Its most effective form-"active" adaptive management-employs management programs that are designed to experimentally compare selected policies or practices, by implementing management actions explicitly designed to generate information useful for evaluating alternative hypotheses about the system being managed.

Adaptive monitoring design – an iterative process that refines the specifications for monitoring over time as a result of experience in implementing a monitoring program, assessing results, and interacting with users.

Attributes - any living or nonliving feature or process of the environment that can be measured or estimated and that provide insights into the state of the ecosystem. The term **Indicator** is reserved for a subset of attributes that is particularly information-rich in the sense that their values are somehow indicative of the quality, health, or integrity of the larger ecological system to which they belong. See Indicator.

Disturbance - any relatively discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment. In relation to monitoring, disturbances are considered to be ecological factors that are within the evolutionary history of the ecosystem (e.g., drought). These are differentiated from anthropogenic factors (see *stressors,* below) that are outside the range of disturbances naturally experienced by the ecosystem.

Driver – a natural agent responsible for causing temporal changes or variability in quantitative measures of structural and functional attributes of ecosystems. See *Ecosystem drivers.*

Ecological indicator – see *indicator*.

Ecological integrity - a concept that expresses the degree to which the physical, chemical, and biological components (including composition, structure, and process) of an ecosystem and their relationships are present, functioning, and capable of self-renewal. Ecological integrity implies the presence of appropriate species, populations and communities and the occurrence of ecological processes at appropriate rates and scales as well as the environmental conditions that support these taxa and processes.

Ecological sustainability – the tendency of a system or process to be maintained or preserved over time without loss or decline.

Ecosystem – a spatially explicit unit of the Earth that includes all of the organisms, along with all components of the abiotic environment within its boundaries.

Ecosystem drivers - major external driving forces such as climate, fire cycles, biological invasions, hydrologic cycles, and natural disturbance events (e.g., earthquakes, droughts, floods) that have large scale influences on natural systems. See *Driver*.

Ecosystem health – a metaphor pertaining to the assessment and monitoring of ecosystem structure, function, and resilience in relation to the notion of ecosystem sustainability and ecological integrity.

Ecosystem management - the process of land-use decision making and land-management practice that takes into account the full suite of organisms and processes that characterize and comprise the ecosystem. It is based on the best understanding currently available as to how the ecosystem works. Ecosystem management includes a primary goal to sustain ecosystem structure and function, a recognition that ecosystems are spatially and temporally dynamic, and acceptance of the dictum that ecosystem function depends on ecosystem structure and diversity. The whole-system focus of ecosystem management implies coordinated land-use decisions.

Focal resources - park resources that, by virtue of their special protection, public appeal, or other management significance, have paramount importance for monitoring regardless of current threats or whether they would be monitored as an indication of ecosystem integrity. Focal resources might include ecological processes such as deposition rates of nitrates and sulfates in certain parks, or they may be a species that is harvested, endemic, alien, or has protected status.

Focal species / organisms – species / organisms that play significant functional roles in ecological systems by their disproportionate contribution to the transfer of matter and energy, by structuring the environment and creating opportunities for additional species / organisms, or by exercising control over competitive dominants and thereby promoting increased biological diversity.

Indicators - subset of monitoring attributes that are particularly information-rich in the sense that their values are somehow indicative of the quality, health, or integrity of the larger ecological system to which they belong. Indicators are a selected subset of the physical, chemical, and biological elements and processes of natural systems that are selected to represent the overall health or condition of the system.

Measures - the specific feature(s) used to quantify an indicator, as specified in a sampling protocol.

Resilience – the capacity of a particular ecological attribute or process to recover to its former reference state or dynamic after exposure to a temporary disturbance and/or stressor. Resilience is a dynamic property that varies in relation to environmental conditions.

Resistance – the capacity of a particular ecological attribute or process to remain essentially unchanged from its reference state or dynamic despite exposure to a disturbance and/or stressor. Resistance is a dynamic property that varies in relation to environmental conditions.

Stressors - physical, chemical, or biological perturbations to a system that are either (a) foreign to that system or (b) natural to the system but applied at an excessive [or deficient] level. Stressors cause significant changes in the ecological components, patterns and processes in natural systems. Examples include water withdrawal, pesticide use, timber harvesting, traffic emissions, stream acidification, trampling, poaching, land-use change, and air pollution.

Vital Signs, as used by the National Park Service, are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values. The elements and processes that are monitored are a subset of the total suite of natural resources that park managers are directed to preserve "unimpaired for future generations," including water, air, geological resources, plants and animals, and the various ecological, biological, and physical processes that act on those resources. Vital signs may occur at any level of organization including landscape, community, population, or genetic level, and may be compositional (referring to the variety of elements in the system), structural (referring to the organization or pattern of the system), or functional (referring to ecological processes).